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GEOLOGICAL SURVEY

Historic vertical displacements in the Salton Trough and adjacent parts of southeastern California

by

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TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

PLATES

TABLES

FIGURES

ABSTRACT

Examination of the available vertical control record for the Salton Trough and some adjoining parts of southeastern California indicates this area has sustained significant and generally episodic vertical displacements during the 20th-century. Regionally developed vertical displacements in southeastern California were reconstructed for various periods based on detailed comparisons among the results of repeated geodetic levelings completed between 1897 and 1981, most of which met first-order standards. In addition, detailed vertical displacement histories were developed for a number of representative Salton Trough bench marks, each based on sequential height determinations along a variety of alternative and independent survey routes. All of the heights and height changes are referred to a virtually invariant San Diego tidal bench mark.

Comparisons among these leveling results indicate that the patterns of crustal deformation within the Salton Trough are changing in both space and time. Historic activity involves periods of relative tectonic quiescence, abrupt episodes of accelerated aseismic movement and tilting, and periodic reversals in tilt directions. The vertical displacement histories of many individual bench marks are characterized by long-term trends or tilts that commonly reflect continuation of deformational trends recognized in the latest Quaternary geologic record. Geodetically defined regional trends reveal a net structural deepening of up to 0.30 m in the Salton Sea area. However, most other areas, including both the Coachella and Imperial Valleys and parts of the southern Peninsular Ranges, have sustained significant net uplift of widely ranging magnitude. The northwestern Coachella Valley and several areas flanking the San Andreas fault-bounded northeastern margin of the trough have sustained cumulative uplift exceeding 0.65 m, whereas net historic uplift in the southern Imperial Valley near El Centro averages about 0.15 m. Moreover, contemporary crustal movement in southeastern California extends well beyond the Salton Trough and involves periodic uplift and tilting within an otherwise relatively aseismic portion of the southern Peninsular Ranges westward nearly to metropolitan San Diego. The magnitude of any net uplift declines rapidly east of the Colorado River but contemporary activity persists at least locally into southwestern Arizona as irregularly defined arching as far east as the Gila Mountains, about 70 km east of Yuma.

The long-term vertical-displacement trends have been periodically or cyclically punctuated, especially in the Imperial Valley, by abrupt and rapidly developed pulses of uplift and subsequent partial collapse, particularly during the 1930's and again in the 1970's. The gross similarities in both the timing and character of these pulses, which are regionally widespread and apparently peak around 0.4 m in the southern Imperial Valley, suggest that these rapid movements may be expressions of accumulating regional crustal strain preceding the occurrence of subsequent large-magnitude earthquakes on the Imperial fault (M = 7.1, May 1940; M = 6.5, October 1979). A more localized episode of accelerated surface tilting along the southern San Jacinto fault probably also preceded the Borrego Mountain earthquake (M = 6.4, April 1968) in its epicentral region west of the Salton Sea. Localized vertical crustal movement has continued throughout the 20th-century along or adjacent to several active fault zones in southeastern California, including the Imperial, Brawley, San Jacinto, San Andreas, and La Nacion faults. Additional evidence drawn from the geodetic record in both the Salton Trough and the Peninsular Ranges is indicative of contemporary vertical offsets along several mapped faults not otherwise known to have sustained historic displacement and several probable but unmapped faults as well.

Regional uplift in southeastern California during the mid-1970's was both coincident in time and apparently continuous with previously recognized and similarly widespread uplift in adjoining parts of southern California. At its probable culmination

around 1974, broadly developed crustal swelling straddled more than 700 km of the southern California plate margin from the southernmost Coast Ranges, through the Transverse Ranges and into the Salton Trough. The magnitude of this uplift was apparently increasing southward when last seen as it crossed the International boundary.

INTRODUCTION

The Salton Trough in southeastern California (fig. 1) is one of the most tectonically active areas in the United States. This region is characterized not only by vigorous seismicity and widespread faulting but by significant and generally aseismic crustal deformation as well (Lofgren, 1978; Wood and Elliott, 1979; Wilson and Wood, 1980; Gilmore and Castle, 1983a; Reilinger, 1984; 1985; Castle and others, 1984; 1986). This complexly deforming depositional basin or series of coalescing basins (Aydin and Nur, 1982) formed remarkably rapidly astride a particularly active segment of the North America/Pacific plate margin during latest Cenozoic time, and probably chiefly during the Quaternary (Sharp, 1982, p. 5). Recent geologic studies of the late Cenozoic tectonic development of parts of this region document episodic or abrupt changes in the style or timing of faulting or folding (Sharp, 1967; 1981; 1982; Babcock, 1974; Todd and Hoggatt, 1979), or in the differential rates and changing patterns of sedimentation and erosion (van de Camp, 1973; Sharp, 1982; Johnson and others, 1983). In fact recent years have seen ever greater appreciation of the role and fundamental importance of rapid and/or episodic change in nature throughout the natural sciences (Axelrod, 1976; Gould and Eldredge, 1977; Alvarez and others, 1980; Bunker, 1982; Gould, 1984). Detailed analyses of repeated geodetic levelings provide another important uniformitarian tool that can significantly assist in unravelling and understanding these temporally and spatially complex deformational patterns.

Earlier examination of the more detailed vertical control record in adjoining parts of southern California disclosed the occurrence of complex cycles of historic crustal deformation characterized by oscillatory vertical movements, ranging up to 0.5 m or more, over a widespread and geologically diverse region (Castle and others, 1984; 1986; Burford and Gilmore, 1984). Rapidly developed pulses of pronounced, aseismic tectonic uplift in various areas commonly are followed by partial or near-total collapse. These periods of uplift may be interspersed with, but more commonly are separated by, longer intervals of relative tectonic quiescence; however, there remains a net uplift. These vertical displacement patterns suggest that the contemporary stress regime in the Transverse Ranges is characterized by periodic, or even cyclical, stress build-up (compression) followed by partial relaxation (dilatation). This interpretation is also independently supported by repeated horizontal strain measurements (Elders and others, 1972; Thatcher, 1979) and temporal correlations between recent changes of gravity, elevation and horizontal strain patterns in southern California (Jachens and others, 1983).

The origin of this complex deformational style remains imperfectly understood. Indeed, the very existence of these phenomena, and by implication, the episodic and/or oscillatory nature of mountain building, has been casually dismissed by some workers who contend instead that because there is no "plausible geophysical mechanism" to account for such observations (Jackson and others, 1981, p. 247), the observations must clearly be in error. However, recent geophysical modeling suggests that such behavior may be the product of relatively shallow, lithospheric decoupling and viscous flow along a very low-angle or subhorizontal detachment zone beneath the seismogenic layer. The decoupling is presumably driven by continuing motion along the especially irregular and broad plate margin south of the Big Bend region of the San Andreas fault system (Rundle and Thatcher, 1980; Lachenbruch and Sass, 1980; Castle and others, 1984). Discontinuous migrating slip beneath or toward the base of the seismogenic section of the San Andreas fault, especially along its locked section, could then lead to alternating pileup and collapse at the surface that need not be characterized by any evident pattern or regularity in either time or space.

This report describes the results of the first rigorous and systematic examination of the recoverable vertical control record for the Salton Trough and adjoining parts of southeastern California. Several previous studies have emphasized selected parts of the Imperial Valley record or have depended on local reference marks whose stability or instability could not be determined (Lofgren, 1978; Wilson and Wood, 1980; Sharp and Lienkaemper, 1982; Reilinger, 1984; 1985). However, this investigation focuses on a broader description of the vertical displacement history of the whole of the Salton Trough where the comparisons, insofar as possible, are reconstructed with respect to an invariant San Diego reference mark. Although the Salton Trough is the primary geographic focus of this report (see approximate limits of study area in fig. 1), a cursory examination of the vertical displacement history of selected parts of the southern Peninsular Ranges has also been necessary and this reconstruction depends in part on survey ties through adjacent parts of southern California and southwestern Arizona.

The results of this investigation indicate that contemporary vertical crustal deformation in the Salton Trough is not only particularly active and widespread but also very complex and irregular in both space and time. Contemporary activity throughout southeastern California is characterized by periods of relative tectonic quiescence, abrupt episodes of accelerated, relatively aseismic movement or tilting, and periodic reversals in tilt directions. Recognized patterns in the historic vertical-displacement field show several interesting relations to the late Quaternary geologic record, may be important indicators of historic fault activity (slip or creep), and display an intriguing temporal and spatial association with several significant historic earthquakes.

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GEOLOGIC SETTING

Recently completed geologic and geophysical studies provide an increasingly detailed and integrated geologic framework for understanding the late Cenozoic tectonic evolution of the Salton Trough (Elders and others, 1972; Hill and others, 1975; Fuis and others, 1982; Sharp, 1982). These studies include detailed investigations of both the seismicity and contemporary patterns of deformation (Lofgren, 1978; Goulty and others, 1978; Thatcher, 1979; Wilson and Wood, 1980; Johnson and Hill, 1982; Castle and others, 1984; this report) and deformation patterns preserved in the recent geologic record (Dibblee, 1954; Stanley, 1966; Sharp, 1967; 1981; Johnson and others, 1983). Many studies have revealed substantial spatial and temporal variations in the rates, style and location of fault movements, in the nature and distribution of contemporary crustal deformation, including periodic reversals in surface tilts, and in local basin subsidence rates. All of these studies show crustal deformation has proceeded vigorously and rapidly in the Salton Trough throughout Quaternary time (Sharp, 1982, p. 5), but movement has probably been relatively episodic in nature and characterized by "one or more... continuing pulses of uplift and deformation" (Axelrod, 1976, p. 38).

Geologic setting. The Salton Trough formed during the last 4-5 m.y. in response to crustal rifting in the Gulf of California (Larson and others, 1968; Elders and others, 1972;

Fuis and others, 1982). It comprises a structurally complex and highly mobile transition zone between oceanic spreading centers in the northern Gulf of California and a broad belt of transform (strike-slip) faulting and basin development along the fragmented and splintered continental fringes of coastal southern California (Crowell, 1974). During Quaternary and late Neogene time, large volumes of fine-grained, marine and non-marine sediments rapidly accumulated within the tectonically subsiding Salton Trough (Sharp, 1982). These deltaic and lacustrine sediments were derived primarily from the drainage basin of the Colorado River (Merriam and Bandy, 1965; Muffler and Doe, 1968) following integration of the ancestral upper Colorado River into a gulfward-directed drainage network by Pliocene time (Lucchitta, 1972; 1979). Sedimentation has been more or less continuous since at least late Miocene time (Dibblee, 1954), marking the earliest stages of crustal rifting and protogulf development. However, the most extensive sequences, perhaps exceeding 6 km in thickness in the central trough (Elders and others, 1972, p. 15; Fuis and others, 1982, figs. 17 and 18), probably were deposited during Quaternary time alone (Sharp, 1982, p. 5).

Masked beneath the thickening sedimentary cover, crustal accretion has proceeded continuously during late Cenozoic time at deep-seated, intrusive spreading centers (Elders and others, 1972) and/or along successively-stepped, leaky transforms (Hill and others, 1975). Incipient development and progressive enlargement in both length and width of pull-apart basins in a strike-slip regime may occur in response to regional crustal attenuation and fracturing associated with rifting or between subparallel, right-stepping, right-lateral faults. With continuing offset, initially small but distinct pull-apart basins develop between adjacent, stepped fault strands and may gradually coalesce into a growing and more complex structural system (Aydin and Nur, 1982). Subsequent growth of the basin in both area and depth allows for both the rapid accumulation of thick sedimentary sequences and, eventually, the shallow intrusion of silicic magmas from depth. Deformation patterns also broaden and become more complex in time as the basin progressively enlarges, not only through incorporation of old (or reactivated) and newly developed fault strands, but also through abrupt changes in regional patterns of sedimentation and subsidence, uplift and erosion, and differential tilting of crustal blocks. Many of these patterns seemingly represent repeated pulses of activity over a number of different time scales (e.g., Wilson and Wood, 1980, table 1) and have been variously interpreted as episodic variations in the relative rates of plate movement along this especially irregular plate margin (Castle and others, 1984), as temporal shifts in relative activity levels or offset rates between nearby fault strands (Sharp, 1981, p. 1760-1761), as a coastward increase in relative crustal spreading rates (Elders and others, 1972, p. 20-22), and/or as other variations (including differential uplift, tilting or rotation) in the nature of interaction between adjacent, left- or right-stepping fault strands (Aydin and Nur, 1982, p. 98-103; Johnson and others, 1983; Matti and others, 1985).

The Salton Trough has simultaneously and/or successively sustained tectonic downwarping, downfaulting, tilting, oblique extension and lateral translation between its bordering ranges along various faults of the San Andreas fault system (Sharp, 1982, p. 5). Numerous major faults in the Salton Trough and adjacent parts of the Peninsular Ranges show direct or geomorphic evidence of historic or Quaternary activity (Sharp, 1982), including the Imperial, Brawley, San Andreas, San Jacinto, Elsinore, Superstition Hills and Superstition Mountain faults (fig. 1). Belts of more intensive folding and movement are concentrated chiefly along the faulted margins of the basin, as in the Mecca and Indio Hills (Dibblee, 1954, p. 26; Sylvester and Smith, 1976; Keller and others, 1982) and rapid anticlinal growth in the Durmid area (Babcock, 1974, p. 327-331). Continuing folding of modern deposits is also indicated by the emergence and erosional truncation of late Pleistocene (and older) beds along the flanks of the trough. More broadly defined crustal downwarping between diverging fault splays has formed the

Mesquite basin within the Imperial Valley (fig. 1), Borrego Valley, and several small playas along the southwestern margin of the trough (Sharp and Clark, 1972; Sharp, 1982, p. 9). Another indicator of continuing crustal activity is that progressively older late Quaternary shorelines of ancient Lake Cahuilla have been progressively more tilted and warped (Stanley, 1963; 1966).

The Salton Trough is the site of recent volcanism and a region of anomalously high heat flow associated with active geothermal areas (Elders and others, 1972, p. 15-16; (Hill and others, 1975; Fuis and others, 1982; Johnson and Hutton, 1982; Fuis and others, 1982; Lachenbruch and others, 1985; see also fig. 1). The deep-seated geothermal circulation system in the Salton Sea geothermal area (fig. 1) is extremely youthful; it was apparently established only during the past 3000-20,000 years (Kasameyer and others, 1984). Rhyolitic volcanic domes near the southeast end of the modern Salton Sea were subaqueously erupted beneath Lake Cahuilla between 16,000 and 55,000 yrs BP (Muffler and White, 1969, p. 157-162). Late Quaternary dacitic volcanism and contemporary seismicity at the Cerro Prieto volcano in northern Baja California are a result of crustal spreading at depth beneath the modern Colorado River delta (Elders and others, 1972, p. 20-22; Johnson and Hutton, 1982; Fuis and others, 1982, p. 42-46).

Important tectonic events in the Quaternary development of the Salton Trough. The recent sedimentary record in the Salton Trough suggests that the early Quaternary locus of maximum tectonic subsidence may have been somewhat farther west and/or north of its present location (Sharp, 1982, p. 11). Early to middle Pleistocene sediments derived from the Colorado River drainage basin (Muffler and Doe, 1968) were deposited as far west as the Vallecito-Fish Creek Mountains area (fig. 1), which may have been the site of one of the earliest Colorado River deltaic complexes in the Salton Trough (Johnson and others, 1983, p. 667), and probably as far north as the southern Coachella Valley (Dibblee, 1954, p. 24-25; Sharp, 1982, p. 11). More than 5 km of marine and nonmarine sediments accumulated in the Vallecito-Fish Creek basin during Pliocene and early Quaternary time (Johnson and others, 1983, p. 664-665). Sedimentation in this area abruptly ceased by middle Pleistocene time, and the entire western margin of the trough including the emerging eastern Peninsular Ranges has since been rapidly uplifted. For example, during the past 900,000 years, average uplift rates in the Vallecito-Fish Creek Mountains have exceeded 5 mm/yr, possibly punctuated by periods of accelerated movement (Johnson and others, 1983, p. 666-667).

By middle Pleistocene time, the main depositional axis of the Salton Trough had shifted abruptly eastward, especially in the Imperial Valley region (Fuis and others, 1982; Sharp, 1982, fig. 4; Aydin and Nur, 1982, fig. 6). Remarkably rapid rates of subsidence have since characterized this area and prodigious volumes of sediments were supplied to the Salton Trough both from reworking of sedimentary deposits in the rapidly emerging western flanks (Sharp, 1982, p. 11; Johnson and others, 1983, p. 666-667) and from the Colorado River watershed. Perhaps in conjunction with a structural constriction or narrowing of the trough, the Colorado River deltaic cone began to prograde rapidly both across the basin and gulfward from an apex near (or north of) Yuma, Arizona by no later than middle Pleistocene time (van de Camp, 1973, p. 828). Periods of rapid deltaic aggradation may also have been triggered or accelerated by repeated sea-level fluctuations during Pleistocene glaciations, periods of increased precipitation and runoff within the Colorado River watershed, relative tectonic uplift of the Colorado Plateau region (Kottlowski and others, 1965; Lucchitta, 1979), the delta area, or both, or some complex combination of these.

Both the timing and nature of the events that led to depositional isolation of the Salton basin from marine incursions of the Gulf of California remain uncertain. Specifically, the existence of a divide between the Salton basin and the Gulf of California may be a strictly sedimentologic feature attributable simply to very high sedimentation rates and especially rapid progradation of the Colorado River deltaic cone across the trough (Sharp, 1982, p. 5; Wilson and Wood, 1980, p. 183). The deltaic cone would thus form an effective depositional dam or barrier preventing subsequent marine incursions into a prexisting subsea-level depression or structural downwarp north of the divide (Babcock, 1974). Alternatively, the divide may have been created by or, perhaps more importantly, maintained during latest Quaternary time through tectonic uplift of the Colorado River delta area (Free, 1914, p. 27; Buwalda and Stanton, 1930, p. 105-106; Gilmore and Castle, 1983a) and/or differential rates of relative tectonic uplift and subsidence within the Salton Trough (this report).

Fossil shoreline deposits and wave-cut terraces of ancient Lake Cahuilla (fig. 1) are especially well developed along the southwestern (Stanley, 1963; 1966) and eastern (Norris and Norris, 1961, p. 615-616; van de Camp, 1973, p. 832) margins of the trough. These successively developed shorelines indicate that the Salton basin was a well-defined, topographically closed depression by late Pleistocene time (at least 32,000 to more than 50,000 radiocarbon-14 yrs BP; Hubbs and others, 1960; Hubbs and Bien, 1967). Intermittently since that time, the Salton basin has been repeatedly inundated by occasional overflow of the ancestral Colorado River. Periodic flooding, which sometimes filled the basin to spillover, was generally followed by partial to complete dessication of the ephemeral, fresh- to brackish-water or saline basinal lakes. The sedimentary remains of such lake cycles in the recent geologic record are represented by the rhythmically interbedded evaporites that occur throughout the thick and otherwise undifferentiated(?) Pleistocene lacustrine sediments of the Borrego Formation in the Durmid area, northeast of the modern Salton Sea (Babcock, 1974, p. 323-324, fig. 4), and probably beneath parts of the Coachella Valley/Salton basin area as well. Moreover, geophysical profiling in this area (Biehler and others, 1964) indicates that asymmetric sedimentary prisms formed in narrow, fault-bounded basins which thicken against the San Andreas fault zone, further suggesting the early development of lacustrine conditions within more areally restricted regimes along the fault-bounded northeastern margin of the Salton Trough (see also Kottlowski and others, 1965, p. 289).

Deformation patterns during late Pleistocene and early Holocene time were characterized by rapid subsidence of the central trough, regionally widespread emergence of the western margins of the trough (Sharp, 1982, fig. 4), and accelerated uplift along the entire, fault-bounded northeastern margin, from the Durmid area (Babcock, 1974), to the Indio and Mecca Hills (Dibblee, 1954) and the San Bernardino Mountains (Dibblee, 1975). Holocene sediments within the Salton Trough are as much as 100 m thick (van de Camp, 1973, p. 829), but their distribution is not known in detail. Although there exists little other information on regional Holocene deformation patterns, local geologic evidence suggests that the Salton basin and Imperial Valley area have been subsiding during recent geologic and historic time. Shoreline deposits formed during successive late Quaternary stands of ancient Lake Cahuilla have been remarkably persistent in their repeated development at nearly identical locations through relatively long (for this area) geologic intervals (Stanley, 1963; Sharp and Clark, 1972; Sharp, 1981; Waters, 1983). Because many shoreline locations are coincident with major, fault-bounded subsurface crystalline basement boundaries, their localized occurrence has been attributed to deep-seated structural or tectonic control (Fuis and others, 1982, p. 41). Finally, the close correspondence between geodetically-defined surface deformation patterns in the Imperial Valley during the 1970's, the configuration of topographic contours within the Salton Trough, and modern shorelines of the Salton Sea suggested to Lofgren (1978, p. 2-3, fig. 3) that patterns of contemporary deformation seem to reflect a continuation of longer-term, late Quaternary tectonic processes.

NATURE OF HISTORIC SURFACE DEFORMATION

Historic surface deformation in southeastern California may be characterized as either tectonic or nontectonic. Nontectonic deformation in turn may be characterized as either artificially- or naturally-induced. Artificially-induced deformation is generally associated with ground-water withdrawls and oilfield and gasfield operations, neither of which are significant in the Salton Trough. Potable ground-water production is virtually non-existent south of the Salton Sea where hot and highly concentrated, heavy metal-rich, geothermal brines are probably more properly considered as contemporary ore-forming solutions (Stanton, 1972, p. 159-162; Elders and others, 1972, p. 22-23). Ground-water withdrawals northwest of the Salton Sea have occurred during the post-1945 period, mostly restricted to the area between Indio and Palm Springs (Castle and others, 1984, pls. 3 and 4). Reductions in water levels in this area probably have produced little if any surface movement owing to their limited extent. Naturally-induced movement derivative from the continuing compaction of geologically recent, fine-grain sediments probably also occurs to at least some degree in the Salton Trough, especially along its axis, but it is very difficult to discriminate. Geodetically defined vertical displacements that cannot be attributed, whether directly or indirectly, to natural compaction or artificial processes are considered tectonic (of whatever origin).

VERTICAL CONTROL DATA

This description of the 20th-century vertical displacement history of the Salton Trough and adjacent areas is based on comparisons among the results of successive geodetic levelings completed between 1897 and 1981 (pl. 1). While most of these levelings met first-order standards, a number of second- and third-order surveys in various parts of the area, primarily developed for engineering or topographic purposes, have also been incorporated into this study.

Height differences have been computed from traditionally corrected observed elevation differences drawn directly from the archival data (summary sheets) of the National Geodetic Survey and from the corrected and uncorrected field elevation differences given in leveling summary books of the Geological Survey. Virtually none of these data have been drawn from the machine-readable file for California (National Geodetic Survey, 1978), since this data set is known to be contaminated by an improperly computed rod excess (Mark and others, 1981, p. 2788-2790). The orthometric corrections required to convert path-dependent observed elevation differences into uniquely defined, true height differences (independent of survey route) are in all cases based on observed gravity rather than theoretical or normal values. Nearly all of these orthometric corrections are machine-integrated results computed from the observed or interpolated gravity values given in the machine-readable data base for California (National Geodetic Survey, 1978). Locally in southern California and throughout Arizona where machine-readable data are unavailable, the orthometric corrections were computed using a manual technique developed by Petr Vanicek (Castle and others, 1984, p. 23), a technique which depends in turn on Bouguer gravity values.

Errors in height determinations. Errors in height differences, with the exception of usually easily detected blunders or busts, are attributable to three major sources: (1) systematic survey error, (2) random survey error, and (3) surface deformation during the course of a specified survey. For purposes of this report, errors attributable to imprecisely formulated orthometric corrections—themselves mathematically-integrated approximations—are thought to have a negligible impact on these measurements (Castle and others, 1984, p. 21-24). The statistically determinable random error in the measured height difference between any two bench marks is proportional to the square root of the distance between them; the random error estimates for various orders and periods of leveling used in this report are specified in table 1. Although the magnitude of the expected random error can be closely estimated, the occurrence and magnitude of systematic error and errors inherent in crustal deformation during the course of a leveling are much more difficult to assess and no simple technique permits their clear discrimination.

Exhaustive analyses of thousands of kilometers of routinely developed levelings in southern California (among other places) designed to test for the occurrence of several height- or slope-dependent systematic errors suggest little if any systematic contamination due to either an inferred rod error (Mark and others, 1981) or the accumulation of an atmospheric refraction error (Castle and others, 1983a; 1983b; 1985; Mark and others, 1986). Moreover, the record of repeated levelings in southern California contains numerous, well-documented examples of the effects of intrasurvey or intersurvey deformation (Castle and Elliott, 1982; Jachens and others, 1983; Castle and others, 1984), whereas clearly documented cases of significant systematic error contamination are comparatively rare (Mark and others, 1981).

A recently discovered and potentially serious systematic error arises from an apparent interaction between the Earth's magnetic field and the pendulum compensators in certain modern automatic levels (Whalen, 1984). Assessments of the effects of these magnetic-deflection errors are severely complicated by the fact that the magnetic response of the pendulum compensators is not only a function of azimuth, but is also instrument design-dependent, instrument-specific, and time-dependent. The only surveys used in this report that may have been contaminated by this error are the 1973/1974 and 1976 levelings leading into the Imperial Valley from Amboy and the Bill Williams River, respectively. This possibility is considered in more detail in the appropriate reconstructions.

Data presentation. The geodetic reconstructions outlined in this report are based on the analysis of a large volume of leveling data which has been summarized and presented in three complementary ways. (1) Maps showing routes and dates of levelings and circuit diagrams have been reconstructed covering various parts of southeastern California and southwestern Arizona that indicate in turn the distribution and quality of the leveling results on which this study is based. Circuit misclosures not only allow for preliminary assessments of possible error contamination, but also provide an important qualitative and quantitative basis for interpreting the general timing, distribution, and magnitude of tectonic movement throughout this region. (2) Vertical displacement profiles along routes of repeated levelings have been compiled from observed elevation differences, orthometrically corrected for path differences where necessary, and generally plotted against a series of progressively younger datums. This method of presentation retains the maximum amount of information (new bench marks are often established and older ones may be destroyed between relevelings), while at the same time revealing short-term changes or reversals in surface tilts. By emphasizing the small-scale details of individual bench mark-to-bench mark displacements, examination of these profiles allows for detection of locally disturbed marks, deformation associated with historic faulting and the regional extent of any detected movement. Profiles of height changes have been arbitrarily grouped into four geographically defined sets for ease of presentation (see also fig. 2): (a) the San Diego area and selected parts of the western Peninsular Ranges, (b) the eastern Peninsular Ranges and western margin of the Salton Trough, (c) the axis of the Salton Trough, including routes extending both east and west of the Salton Sea, and (d) across and within the Imperial Valley. (3) Vertical displacement histories for representative bench marks throughout the region (fig. 2) have been developed from reconstructions based on as wide a variety of alternative and independent but temporally restricted leveling routes as the data permit. These reconstructions provide an important regional perspective by showing how historic displacement patterns have changed in different areas through time.

REFERENCE MARK

Insofar as possible, all geodetic comparisons and reconstructions in this report have been referred to a demonstrably stable reference mark adjacent to the San Diego tide station. Another tidal bench mark at San Pedro has been used as an alternative starting point for several reconstructions, and its height through time can be closely approximated with respect to San Diego. The use of several other bench marks in southwestern Arizona, which can be shown to have remained virtually invariant with respect to the San Diego control point, provide a way to reconstruct additional heights as if the levelings emanated directly from San Diego. Supplemental use of these southwestern Arizona bench marks as alternative starting points has permitted a considerably more detailed assessment of vertical displacement patterns in southeastern California than otherwise would have been possible. In some cases, where spatial or temporal isolation of surveys or networks requires the use of local control points, a detailed explanation constraining the range of possibilities accompanies the reconstruction.

Bench mark M57 (record height = 5.8830 m), located adjacent to the primary tide station at the Municipal Pier, downtown San Diego, is the basic control point to which all heights and height changes in this report have been referred. Both oceanographic and geologic evidence indicate that this mark has remained essentially fixed with respect to a tectonically invariant datum (such as the reference ellipsoid) through both historic and recent geologic time (Castle and Vanicek, 1980, p. 291-292). A linear regression through the 19-yr mean sea-level curve for the San Diego tide station indicates that sea-level at San Diego has been rising at about 1.93 mm/yr with respect to the adjacent tidal bench marks (Castle and Elliott, 1982, fig. 16). This rate is slightly greater than the average long-period (1940-1973) eustatic sea-level rise for the conterminous United States of about 1.5±0.3 mm/yr (Hicks and Crosby, 1975). The close correspondence between these two values suggests that the San Diego tide station has been rising at such a slow rate with respect to any arbitrarily defined invariant datum that it can be treated as if it were tectonically stable. Geologic studies of emergent marine terraces in this area, which show that during the past 120,000 yrs the San Diego area has been rising with respect to a tectonically invariant datum at an average rate of about 0.08-0.41 mm/yr, independently support this conclusion, (Lajoie and others, 1979). Moreover, K. R. Lajoie (oral communication, 1981) found no measurably significant vertical displacements during latest Quaternary time within the central San Diego area where the San Diego tide gauge has operated continuously since 1927.

The results of comparisons among repeated levelings in the central San Diego area (pl. 2) suggest relative stability within this area during the 1927-1978 period of record. Bench mark M57 has remained essentially invariant with respect to numerous adjacent bench marks in the Municipal Pier area. Differential vertical displacements within metropolitan San Diego west of the La Nacion fault (pl. 2, b and c) nowhere exceed 0.014-0.015 m (estimated random error is ± 0.005 m, or less). This is less true northward toward La Jolla (pl. 2a), where more irregularly defined vertical movements range up to about 0.025 m along an apparently active strand of the Rose Canyon fault system (Ziony and others, 1974, sheet 2; Jennings, 1975).

Because its history with respect to M57 is known, bench mark Tidal 8, adjacent to the San Pedro tide station (pl. 1), can be used as an alternative starting mark (Wood and Elliott, 1979; Castle and others, 1984; 1986; Burford and Gilmore, 1984). The least ambiguous first-order geodetic ties between San Diego and San Pedro were completed in 1931/1932/1933 (where a correction of about 0.01 m must be made for compaction-induced subsidence during a 1-yr junction interval at Santa Ana) and in 1968/1969 (table 2). The results of these levelings can then be corrected to any selected starting date by allowing for the 1.56 mm/yr uplift of the San Pedro tide station with respect to San Diego (Castle and Elliott, 1982, figs. 9 and 16).

Reconstruction of the vertical displacement histories of two representative bench marks in southwestern Arizona with respect to M57, San Diego (fig. 3), indicates that these marks have remained virtually unchanged with respect to M57 throughout the 20th-century. Because geologic and geomorphic evidence (Lucchitta and Suneson, 1983) suggest that the Bill Williams River area and adjoining parts of southwestern Arizona have remained tectonically quiescent during approximately the past 7 m.y., these results provide an important and additional indication of the inferred historic stability of the San Diego reference mark. Moreover, the historic stability of these southwestern Arizona bench marks indicates that levelings propagated out of these marks can be treated as the equivalents of those emanating directly from M57, San Diego.

One representative southwestern Arizona bench mark, 22Q, is located near the Bill Williams River about 25 km east of Parker Dam (pl. 1). Orthometric heights for this mark, previously established with respect to the San Pedro tidal reference mark (Gilmore and Elliott, 1985, tables 38-41), have been reconstructed with respect to M57, San Diego (fig. 3a). Although this mark was not established until the early 1930's, a 1906 height for 22Q has been computed from a combination of the results of 1906, 1906/1907, and 1909 levelings between San Diego, Colton, Barstow, Goffs, and Yucca along with 1927 and 1931 levelings between Yucca and 22Q, coupled with an assumption of invariance between Yucca and 22Q between 1906 and 1931 (Appendix table A1).

The second representative southwestern Arizona bench mark for which successive heights have been developed is 010, Hassayampa, located about 50 km north of Gila Bend (pl. 1). Reconstructions of successive heights for bench mark 010, Hassayampa, with respect to M57, San Diego, which were first outlined by Castle and others (1985), are repeated here in fig. 3b (Appendix tables B1-B4). Again, although 010 is not known to have existed prior to its inclusion in the 1927 leveling, a 1905 height has been computed for this mark based on the results of 1897, 1902, and 1905 levelings between San Diego, San Pedro, Colton, Yuma and Gila Bend and 1927 leveling between Gila Bend and Hassayampa, coupled with an assumption of invariance between Gila Bend and Hassayampa during the period 1905-1927 (fig. 4). Although the 1981 Hassayampa height seems to be anomalous (fig. 3b), this value depends on 1981 leveling extending westward only to El Centro, coupled with 1978 leveling into San Diego. The 1978-1981 junction interval at El Centro brackets the occurrence of the nearby Imperial Valley earthquake of October 1979 (M = 6.5), which was identified with both extensive surface rupture (Sharp and others, 1982) and continuing postseismic vertical movement (Sharp and Lienkaemper, 1982) in this area. Nevertheless, a comparison of the results of the 1981 leveling against 1978 leveling between El Centro and the Holtville area (fig. 5) discloses little if any differential movement between these end points during the 1978-1981 interval. Regardless, and in spite of the retention of vertical integrity between El Centro and Holtville, because both geodetic and geologic evidence strongly support the long-term tectonic stability of Hassayampa, an alternative interpretation (and the one adopted in this report) is that the El Centro area sustained net subsidence of about 0.03 m with respect to M57 (and hence, 010) between 1978 and 1981.

DETAILED GEODETIC RECONSTRUCTIONS

This characterization of the vertical displacement history for the Salton Trough and some adjoining areas during the 20th-century depends on the reconstruction of sequentially determined heights for a number of representative bench marks throughout the region (fig. 2). These reconstructions can be ordered either geographically (spatially) according to survey route (e.g., Castle and others, 1984; 1986) or according to explicitly defined time frames, even if overlaping (temporally) The reconstructions in this report are arranged chronologically and their presentation is subdivided into 12 temporally defined epochs. Epochs are of necessity restricted to periods of relatively continuous and regionally widespread levelings across the Salton Trough and Peninsular Ranges, and the period between these successive relevelings within a given time frame ranges from about a year and a half to as much as 25 years. Within each epoch, discussion of the individual reconstructions proceeds from north to south roughly along the axis of the Salton Trough.

Reconstruction of vertical displacement histories for selected Salton Trough bench marks are based on various combinations of more-or-less temporally constrained leveling results and include any necessary assumptions or corrections (refer to Appendix). Each reconstructed height for each representative bench mark is outlined in detail in the appendix. Due to the limited life span of many of the earlier bench marks in particular, the development of the most detailed vertical displacement histories possible depends in some cases on ties to nearby common marks and assumptions of invariance between these marks (see Appendix). Wherever possible, these heights have been developed from as wide a variety of alternative and independent routes as available for the indicated time frame. Most of those heights shown as solid dots in vertical-displacement plots are generally well-constrained; values shown as open circles are associated with a greater degree of uncertainty, owing chiefly to unverifiable or questionable assumptions of invariance which may span known or suspected periods of crustal activity. Nonetheless, these less certain values are included because they often provide the only evidence, albeit somewhat qualitative, of displacements within certain time periods.

<u>Early 1900's</u>. Those levelings treated as early 1900 vintage surveys were completed between 1897 and 1906 (pl. 1). Turn-of-the-century levelings provide two separate and independent early 1900's surveys out of San Diego, both of which lead into the Salton Trough via Colton. The least ambiguous early datum is based on the results of 1897 third-order levelings from San Pedro via Los Angeles and Ontario to Colton (pl. 1), coupled with a 1931/1932/1933 geodetic tie between San Diego and San Pedro which has been corrected to an 1897-equivalent by allowing for relative movement between the San Diego and San Pedro tide stations during the period 1897-1931/1932/1933 (see "Reference Mark"). A first-order 1906 survey leads into Colton directly from San Diego, via Oceanside, Santa Ana and Arlington (pl. 1).

Direct comparison of the results of the 1897 and 1906 levelings produces an approximately 0.13 m discrepancy in an early 1900's starting height at Colton. Several other lines of evidence also indicate that Colton sustained net regional uplift of about 0.13 m with respect to San Diego during this period (Castle and others, 1986). The especially well-balanced misclosures around two contiguous circuits involving these surveys (fig. 6) are highly suggestive of intersurvey deformation along their common leg from San Diego to Colton between 1897 (or 1902) and 1906. Comparison of the results of the 1906 leveling against a partial 1897/1899 third-order datum extending southward from Colton to about 10 km north of Oceanside (the southernmost extent of late 1890's leveling along this route) shows a broad regionally developed uplift of about 0.15 m extending as far south as San Juan Capistrano, then uniformly declining to about 0.07 m near Oceanside where the comparison ends (Castle and others, 1986, pl. 7). That such movement probably occurred after 1902, and hence subsequent to the propagation of the 1902 leveling southeastward into the Salton Trough from Colton, is strongly supported by the excellent agreement between the misclosure around the 1902/1906/1926/1927 circuit Colton-

Mecca-Ogilby-El Centro-San Diego-Santa Ana-Colton (fig. 6) and the magnitude of the 1897-1906 uplift at Colton (Castle and others, 1986, pl. 7). Moreover, significant measurement contamination of either the third-order 1897 levelings or 1902 survey in the Salton Trough is unlikely because both surveys were double-rodded and comparisons with subsequent levelings are in good agreement. Moreover, both these surveys were also involved in the 1902 Hassayampa reconstruction (fig. 3b), which produces a height that agrees amazingly well (especially considering the distances involved) with those based on subsequent first-order levelings into this bench mark along other routes. Thus the early 1900's heights developed for various Salton Trough bench marks in this report are based on the results of the 1897 third-order survey between San Pedro and Colton, which was completed prior to an acceleration of tectonic activity in southern California sometime after 1902 (Castle and others, 1986).

From a tie at Colton, two alternative turn-of-the-century levelings extend along the axis of the northern Salton Trough and provide a basis for establishing early 1900's heights for several representative bench marks in this area. The primary early 1900's Salton Trough datum is based on results of the third-order 1902 survey, which was rapidly propagated between Colton and Yuma (USGS summary book 9488). The 1902 heights for representative bench marks at White Water (fig. 7), Indio (fig. 8), and Mecca (fig. 9) are derived from a combination of 1897 third-order levelings between San Pedro and Colton (see above) and the results of 1902 leveling southeast from Colton.

An earlier connection between Colton and points southeastward into the Salton Trough can be established from a combination of 1898 and 1901 third-order levelings (pl. 1). The 1898 value for White Water (fig. 7) is based on a direct tie between the 1897 San Diego-San Pedro-Los Angeles-Colton results and 1898 leveling between Colton and White Water. However, the earlier Indio and Mecca reconstructions are complicated by an indirect tie between the 1898 and 1901 levelings at a Palm Springs junction bench mark that may have sustained either differential coseismic collapse associated with a nearby December 1899 earthquake or was otherwise disturbed during the intervening approximately 3-yr junction interval (Castle and others, 1986). To avoid this complication, the 1901 heights shown for Indio (fig. 8) and Mecca (fig. 9) are based on the 1898 survey into White Water (see above), coupled with an assumption of invariance between White Water (the eastern end of the 1898 survey) and the western end of the 1901 leveling (about 8 km southeastward) into Indio and Mecca (pl. 1) during the period 1898-1902. A comparison of the results of the 1902 leveling against this composite 1898/1901 datum (fig. 10) shows little differential movement between Colton and Indio/Mecca during this period. The apparent signals southeast of Colton and northwest of Indio (fig. 10) may be coseismic displacements associated with nearby earthquakes during March and December 1899, respectively (Castle and others, 1986).

Heights for representative bench marks in the Imperial Valley can be derived from a tie with the 1902 survey at Old Beach (Niland) and the results of either 1904 or 1905 third-order levelings leading southward into the Imperial Valley. However, neither of these surveys provides problem-free ties into representative Imperial Valley bench marks owing to the generally discontinuous nature of their runnings, differences in leveling routes, and their dependence on different reference marks (USGS summary books 5819 and 5820). In addition, two 0.305-m (even 1-ft.) busts have been identified in 1904 ties between Imperial, Calexico and Holtville (and other areas not described in detail in this report) and are revealed by the anomalously large circuit misclosures south of Imperial (fig. 11). Other large circuit misclosures in the composite 1904/1905 (fig. 11a) and 1905 (fig. 11b) Imperial Valley networks may reflect pre-April 1906 (Johnson and Hill, 1982, p. 18) differential movement across the Imperial or Brawley fault zones (see also fig. 12). Alternatively, these values may be due to intra- or intersurvey movement during the 1904-1905 junction intervals at several local bench marks used as ties between these levelings or the local accumulation of measurement error along several cross-country routes through uncompacted sandy terrains where simple wooden stakes served as temporary bench marks. In addition to a general lack of common marks along the direct route south of Brawley (fig. 11a), these reconstructions are further complicated by generally poor bench mark descriptions in both summary books (5819 and 5820) and ambiguous, multiple listings and adjustments in the 1904 leveling (USGS summary book 5819). Several misclosures shown in fig. 11, which do not duplicate values shown in correspondence attached to USGS summary book 5819, may be nothing more than the result of my misreading or misinterpretation of the original, and now repeatedly overwritten, field notes. Nevertheless, reasonably well-constrained 1904 and 1905 heights can still be established for representative Imperial Valley bench marks at both Rockwood (fig. 13), about 7 km north of Brawley, and El Centro (fig. 14). Even though ties between the 1902 and 1904/1905 levelings are made through Old Beach (now Niland), and many subsequent repeated levelings in this area are available, no early 1900's heights can be satisfactorily established for any representative bench mark near Niland. In fact, no early 1900's bench marks between Niland and Mecca are known to have survived as late as the next subsequent releveling in 1928.

The least ambiguous 1904 height (solid dot) for Rockwood (fig. 13) is based on what is believed to be the original notes of the leveling crew. Because this particular bench mark, -162Y, is so vaguely described and because its original elevation has been repeatedly readjusted (USGS summary book 5819), either of the other two 1904 values (shown as open circles in fig. 13) might also be considered as reasonable alternatives (refer to Appendix table H1, note 4). The 1904 height for El Centro (fig. 14) is based on 1904 leveling directly into Carbarker Junction (fig. 11a), coupled with a 1926/1927 tie between bench mark -50Y at Carbarker Junction and El Centro, which did not then exist. Based on a comparison with both the 1904 and 1905 heights directly into El Centro, a 0.305-m (even 1-ft) bust has been identified in the alternative route via Silsbee between the junction mark west of Imperial and Heber (fig. 11a). Removal of this bust reduces the misclosure of the 1904 circuit Imperial-Heber-Silsbee-Imperial to only -0.006 m (fig. 11a). In conjunction with the generally small magnitude of closures in several contiguous 1904 circuits to the north and east, this small resulting misclosure suggests that the very large misclosure of the adjoining 1904 circuit Calexico-Carbarker Junction-Holtville-International Boundary Monument (IBM) 219-Calexico cannot be attributed to a compensating blunder in their common segment from Heber to a junction mark immediately south of Carbarker Junction (fig. 11a). Thus the entire segment from Heber to Carbarker Junction to Holtville involved directly in these reconstructions may be considered as free of blunders.

The source of this large 1904 misclosure, which seemingly enlarges in magnitude around a nearly identical circuit based primarily on 1905 levelings (fig. 11b), must be attributed to either two or more blunders elsewhere around this circuit or significant offset across the Imperial fault during the survey interval. The results of the 1904 leveling between Holtville and IBM 219 are especially suspect as they cannot be tied into a continuous circuit with adjacent 1904 levelings (fig. 11a) and are appended with the note "cannot be adjusted" in USGS summary book 5819. The 1905 releveling along a possibly or nearly coincident route depends on different ties to temporary bench marks in Holtville (fig. 11b). Comparisons of the results of 1904 and 1905 levelings from Carbarker Junction south toward Calexico check closely, but an additional source for this large closure may be tied to measurement error in the levelings between various International Boundary Monuments. Preliminary comparisons of 1904 and 1905 height differences between several monuments reveal at least one apparent 0.305-m (even 1-ft.) bust, and comparisons of averaged 1904/1905 heights for various IBMs against values from an earlier (1890's) U.S. Boundary Commission report (referred to only indirectly in correspondence dated August 1905 attached to USGS summary book 5819 and not yet recovered) are also characterized by two abrupt, approximately 0.305-m (even 1-ft.) offsets. However, even after removal of these several postulated busts, these preliminary reconstructions suggest that a net component of relative uplift (or up-to-the-east tilting or downdropping east of the Imperial fault) along the length of these comparisons was in the process of developing in this area by 1904 or 1905.

In marked contrast to these rather involved 1904 reconstructions, the 1905 heights for both Rockwood (fig. 13) and El Centro (fig. 14) are each based simply and directly on the results of the 1905 leveling into the Imperial Valley from a tie to the 1902 survey at Old Beach (Niland). South of Brawley, the 1905 survey follows a different route from the 1904 leveling, and although their routes cross at Imperial, they are not joined together again until south of Carbarker Junction (fig. 11b). Comparative profiles in the Imperial Valley based on as many early 1900's bench marks as were subsequently recovered (fig. 12) demonstrate the occurrence of a modest differential tilt between 1904 and 1905 north of Carbarker Junction. At least a part of this offset may have occurred along the Imperial fault, but the wide spacing between these early bench marks precludes a detailed assessment of this movement. Finally, it should be possible to establish a 1905 height for bench mark -10Y at Holtville (fig. 12), also recovered in 1905, with respect to Carbarker Junction through a tie with any (?) of several 1905 lines in the Holtville area (USGS summary book 5820), but at this point it sure beats the hell out of me.

Early 1900's heights for a representative bench mark near Campo (fig. 15), in the southern Peninsular Ranges, can be established from a direct tie to San Diego based on the results of 1901/1902 third-order levelings (pl. 1). Because bench mark Y57 (fig. 1), the representative Campo mark, did not exist prior to its inclusion in the 1926/1927 leveling (NGS line 82606), the early 20th-century heights depend on several subsequent ties between Y57 and older bench marks to both the east and west of Campo (table 3). The range of these values produces significantly different heights; however, the values shown in fig. 15 are based on 1955 second-order ties, which produce the largest obtainable discrepancy (worst case). The 1901 Campo height of 680.3978 m (fig. 15) is based on the results of 1901/1902 levelings between San Diego and bench mark 2323, Potrero, about 6 km west of Campo, and a 1955 second-order tie between bench marks 2323 and Y57. An alternative early (1902) Campo height of 680.4957 m (fig. 15) is based on the results of these same 1901/1902 surveys to bench mark 2543, about 7 km east of Campo, and a 1955 second-order tie between bench marks 2543 and Y57. Substitution of either the 1926/1927/1938 or 1968/1970 height differences between Y57 and bench marks 2323 or 2543 (table 3) reduces the 0.1 m discrepancy between the 1901 and 1902 values (fig. 15) by 0.03-0.07 m. This suggests some subsequent differential tilting developed between the early marks consistent with uplift and westward tilting of the southwestern Peninsular Ranges in this area during the period 1901-1970 (see also pl. 2c).

1926/1928. The first regionally widespread, (first-order) network was established throughout southeastern California and southwestern Arizona during the period 1926-1928 (pl. 1). Representative 1926-1928 heights for Salton Trough marks have been derived from a direct tie between San Diego and the southern Imperial Valley along the route of the (now abandoned) San Diego and Arizona Eastern Railroad. The 1927 heights at Campo (fig. 15) and El Centro (fig. 14) are both based on this direct 1926/1927 tie from San Diego. Northward from a tie at El Centro, the results of a first-order 1928 survey were used in reconstructing 1927 heights for representative marks at Rockwood (fig. 13), Niland (fig. 16), Mecca (fig. 9), Indio (fig. 8), and White Water (fig. 7). These reconstructions suggest little net movement in the Imperial Valley region from about 1902 through 1927. This is also implied by the very small misclosure of the 1902/1906/1926/1927 circuit San Diego-Santa Ana-Colton-Mecca-Ogilby-El Centro-San Diego (fig. 6), where allowance is made for the 1902-1906 uplift at Colton (see above).

The height difference based on the 1928 first-order leveling between Colton and El Centro has been distorted by an error on the order of about 0.3 m, a conclusion disclosed in the large misclosures involving the leveling (Castle and others, 1986, fig. 25) and in comparisons with successive levelings (pl. 3). Because there is no indication of the accumulation of any height- or slope-dependent systematic error, Castle and others (1986) attributed this distortion to significant intrasurvey deformation between El Centro and at least Indio, even though this survey was completed in less than three months (NGS line L-11). A comparison of Imperial Valley misclosures developed from the successive results of 1926/1927/1928, 1931, and 1941 levelings against a 1935 second-order survey (fig. 17) suggests that no overall differential tilting affected the area of the Imperial Valley circuit between 1926/1927/1928 and 1941, although vertical but uniform block movement of the area as a whole is not precluded. Accordingly, intrasurvey movement during the course of the 1928 leveling must have occurred northwest of Niland. The effects of intrasurvey distortion in the 1928 leveling are particularly apparent in the northern Salton Trough, as clearly shown through reconstruction of an alternative 1928 height for White Water (fig. 7). This alternative height of 345.0755 m is based on the results of 1923/1924/1926 levelings between San Pedro and Colton via Los Angeles and Ontario (pl. 1) and the 1928 leveling from Colton to White Water, coupled with an assumption of invariance at Colton between 1923/1924 and 1928 (Castle and others, 1986, fig. 26). This independently determined 1928 value plots about 0.3 m above the 1927 height of 344.7699 m determined along the Campo-El Centro-Mecca route (fig. 7) and indicates that tectonic uplift at White Water may be well in excess of 0.5 m between 1902 and 1928.

A 1927 height for a representative bench mark at Santa Ysabel (fig. 18) can be established through an alternative 1927 leveling leading northeast from San Diego via La Mesa, Lakeside and Ramona (pl. 1). This 1927 leveling also allows reconstruction of an alternative 1927 height of -4.3057 m for Indio via Santa Ysabel and Aguanga when combined with the results of a 1939 second-order survey between Aguanga and Indio (pl. 1) and an assumption of invariance between Aguanga and Indio during the period 1927-1939. The small misclosure around the 1926/1927/1928/1939 circuit San Diego-Santa Ysabel-Aguanga-Indio-El Centro-San Diego (fig. 19) may simply be fortuitous owing to a balance between intrasurvey movement along the 1928 route northwest of Niland and compensating 1927-1939 tilting between Indio and Aguanga. Nonetheless, this alternative 1927 Indio height conforms remarkably well with that developed along the primary route via Campo and El Centro (fig. 8).

Early 1930's. Levelings completed between 1931 and 1935 are grouped together as an early 1930's network, closing on 1926/1928 levelings throughout southeastern California and southwestern Arizona (fig. 20). Although these levelings are regionally widespread, their spatially and temporally discontinuous distribution (pl. 1), coupled with evidence of significant crustal activity during this period, complicates and restricts their use. Repeated levelings within the Salton Trough during this period extend along and across the Imperial Valley (pl. 4) and parts of the Coachella Valley (pl. 3) but the two can be only indirectly related. Widespread crustal deformation in southeastern California during the 1930's contrasts markedly with the relative tectonic quiescence of southwestern Arizona, where misclosures are generally small even among the temporally poorly-constrained levelings in southwestern Arizona (fig. 20, see also fig. 4).

Large misclosures characterize many of the late 1920's/early 1930's circuits in southeastern California (fig. 20), even though these levelings are tightly constrained in time. These values are suggestive of widespread and significant regional crustal deformation during the period 1926-1935. In particular, the results of the 1931 first-order leveling along the then-projected route of the Colorado River aqueduct southwest from Freda Junction (fig. 20) have been previously identified as being distorted by the effects of intrasurvey movement (Castle and others, 1984). This distortion is especially evident in the magnitudes of misclosures around two northern Salton Trough circuits based on substitutions of 1928 and 1931 levelings along the primary Coachella Valley line (fig. 21). The -0.1956-m closure around the 1928/1931 circuit Cabezon-Fargo Junction-Indio-

Cabezon is reduced to -0.0713 m through substitution of all 1931 levelings. Nevertheless, this all-1931 misclosure is still well above the ±0.0187-m random error estimate for this 155-km circuit, even though this first-order survey was completed in less than three months (NGS line L-7407). A similarly large discrepancy between closures based on 1928 and 1931 levelings in the Banning-Indio-Aguanga-Banning circuit (fig. 21) is equally suggestive of the magnitude and rapidity of aseismic tectonic tilting developed in the northern Salton Trough during the late 1920's and the early 1930's (see also pl. 3).

Reconstructions of several independently determined early 1930's heights for White Water (fig. 7) provide additional clues to the nature and magnitude of regional uplift occurring during this time. The primary 1932 height of 345.0955 m is based on the 1932/1933 survey from San Diego to Santa Ana, 1931/1932 leveling between Santa Ana and Riverside and 1931 leveling from Riverside to White Water via San Jacinto and Banning (pl. 1). An alternative 1932 White Water height of 345.0000 m is based on the 1932/1933 leveling from San Diego to Fallbrook, coupled with a 1927 tie between Fallbrook and Aguanga, 1932 leveling from Aguanga to San Jacinto, and 1931 leveling between San Jacinto and White Water via Banning. The 1931 White Water height of 345.1723 m is based on the 1931/1932/1933 tie between San Diego and San Pedro, coupled with 1931/1932 levelings from San Pedro via Los Angeles and Ontario to Riverside and the 1931 survey between Riverside and White Water. If this San Pedro-based 1931 White Water height was instead based on the results of 1931/1932 levelings between San Pedro and Riverside via Santa Ana (a route more directly comparable to the primary 1932 height, above), it would produce another alternative 1931 height of 345.1141 m.

A comparison of late 1920's and early 1930's heights developed for White Water (fig. 7) displays a spread of almost 0.40 m. Thus, the total uplift at White Water with respect to San Diego between the early 1900's and early 1930's may be as much as 0.65 m. The absence of intervening levelings precludes a clear determination of whether this uplift occurred uniformly through the period, at an average rate of about 0.02 m/yr, although the broad range of late 1920's/early 1930's values, coupled with several indications of continuing intrasurvey movement, strongly suggests that the major pulse of uplift probably developed during the late 1920's and early 1930's.

A comparable series of early 1930's heights has also been reconstructed for Indio (fig. 8) based on the same routes used to develop White Water heights (above), coupled with a 1931 tie into Indio. In addition, three heights derived from southwestern Arizona bench marks are shown for comparative purposes, and although these values may be distorted by intrasurvey movement, they nonetheless cluster well with the San Diego-based heights. Cumulative uplift at Indio amounted to about 0.10 m by the early 1930's. Profiles involving 1931 levelings along the northern Salton Trough (pl. 3) are based on the primary 1932 reconstruction via Santa Ana, Riverside, San Jacinto, and Banning, which represents an average of the broad range of available early 1930's values (see especially fig. 7).

Evidence of rapidly developing and widespread regional uplift in southeastern California by the early 1930's extends throughout much of the Salton Trough and into parts of the Peninsular Ranges as well. Although the principal Imperial Valley crossings were releveled during 1931 (pl. 1), these surveys cannot be directly related to early 1930's Coachella Valley levelings. The only clue to the nature of movement in the Imperial Valley during the early 1930's depends on a comparison between 1931/1933 and 1971/1972 levelings referred to a local bench mark at Palo Verde, near the Colorado River about 20 km south of Blythe (pls. 1 and 5). This rather involved reconstruction (see "1971/1972") suggests that the southern Imperial Valley (and specifically, El Centro) may have sustained a net regional uplift of at least 0.10 m between about 1927 and the early 1930's (fig. 14).

Regional uplift in the Peninsular Ranges north of San Diego is much more clearly defined by the early 1930's. A comparison of 1932/1933 leveling against a 1906 survey (already noted to define an up-to-the-north tilt against an earlier 1897/1899 survey) documents a pronounced, roughly uniform up-to-the-north tilt, resulting in uplift of about 0.07 m at Oceanside, about 0.16 m near San Juan Capistrano, and finally leveling off at about 0.30 m or more from Santa Ana north (Castle and others, 1986, pl. 7). Although there were few early 1930's levelings within the Peninsular Ranges, maximum culmination of regional uplift in southeastern California during the 1930's may actually have occurred by about 1935. This inference is based primarily on a comparison of misclosures around the San Diego-Santa Ysabel-Jacumba-San Diego circuit developed from 1926/1927, 1935 and 1939 levelings (fig. 22). Specifically, both these misclosures suggest that the southwestern Peninsular Ranges sustained significant relative uplift between 1926/1927 and either 1935 or 1939, with development of a modest but irregularly defined up-to-the-north tilt from Jacumba to Santa Ysabel between 1935 and 1939 (pl. 6).

1938/1939. Levelings completed during the late 1930's consist of an extensive network of 1938 third-order levelings in the southwestern Peninsular Ranges (fig. 23), and various 1939 second-order levelings through the Peninsular Ranges and parts of the Salton Trough (pl. 1). Anomalously large misclosures characterize many parts of this 1938/1939 network, developed against 1926/1927 surveys extending eastward to Jacumba and Santa Ysabel and a 1932/1933 survey northward into Del Mar (fig. 23). Various vertical displacement profiles involving 1938/1939 levelings (pls. 2, 6 and 7) show that a widespread regional uplift throughout southeastern California was clearly well-defined by the late 1930's, affecting many parts of the Peninsular Ranges and the Salton Trough. Alternatively developed heights for representative Peninsular Ranges bench marks provide a range of values suggesting average uplift of about 0.20 m at Campo and about 0.10 m at Santa Ysabel during the period 1927-1938/1939. Representative 1938/1939 heights for several central Salton Trough bench marks can thus be established directly from these averaged values of uplift at Santa Ysabel and Campo based on 1939 levelings into the Salton Trough and can be readily extrapolated to several other nearby marks.

Relatively large misclosures in the 1938 network in the immediate vicinity of San Diego (fig. 23) somewhat complicate reconstruction of representative 1938 Campo heights, resulting in a range of values that can be developed from various combinations of levelings leading directly east and southeast from San Diego (fig. 15). Starting with the northernmost route, this 1938 Campo height of 680.4527 m depends on 1927 leveling from San Diego to La Mesa, coupled with 1938 levelings from La Mesa via Jamul, Dulzura and Barrett Junction to Campo. A second Campo height of 680.5191 m is based on 1926/1927 leveling between San Diego and National City and 1938 levelings extending eastward from National City via La Presa, Jamul, Dulzura and Barrett Junction. Two separate heights are based on 1926/1927 leveling between San Diego and Chula Vista, the first one of 680.4344 m derived from 1938 levelings into Campo via Jamul, Dulzura and Barrett Junction and a second of 680.3972 m based on 1938 levelings from Chula Vista via Otay Dam, Kuebler Ranch, Dulzura and Barrett Junction. A fifth 1938 Campo height of 680.3852 m, along the southernmost route, is based on the 1926/1927 survey between San Diego and San Ysidro, coupled with 1938 levelings from San Ysidro via Kuebler Ranch, Dulzura and Barrett Junction; this height has been corrected for the 0.051-m uplift that occurred at or adjacent to the San Ysidro junction mark, W57, between 1926/1927 and 1938. This abrupt offset is identified both by exceedingly well-balanced, compensating misclosures in the 1938 circuits immediately west and east of San Ysidro (fig. 23) and by abrupt steps of identical magnitude at San Ysidro in vertical-displacement profiles of subsequent 1955 and 1968/1970 uninterrupted relevelings from San Diego against a 1926/1927 datum (pl. 2c). The step appears to be spatially coincident with the

La Nacion fault immediately east of metropolitan San Diego (Ziony and others, 1974, sheet 2; see also fig. 1) and is consistent with the occurrence of about 0.051 m of relative uplift athwart or immediately east of this zone between 1926/1927 and 1938 (pl. 2). In the absence of a direct 1938 tie to San Diego, the starting height for the 1938 profile at San Ysidro in pl. 2c is defined by the mean of these two 1938 misclosures. Movement along the northerly extension of this fault zone (fig. 1) may also account, or partly account, for the anomalously large 1926/1927/1938 circuit closures east of the San Diego/Chula Vista area (fig. 23).

A series of 1938/1939 heights can also be developed for the selected Santa Ysabel bench mark (fig. 18) from the results of the 1938 Campo reconstructions, coupled with 1938/1939 levelings northward from Campo via Pine Valley, Descanso and Julian, or eastward from San Diego via Miramar, Poway, and Ramona. The five representative 1939 height values shown for Santa Ysabel (solid dots, fig. 18) are based on the Campo reconstructions described above, coupled with 1938 third-order leveling from Campo to Pine Valley and 1939 second-order leveling from Pine Valley to Santa Ysabel via Julian (see Appendix tables J2-J6). For comparative purposes, 1938 Santa Ysabel heights (solid triangles, fig. 18) can also be independently developed from 1938 levelings leading northeastward from San Diego via the Miramar/Poway area, where circuit closures are generally small (fig. 23). The magnitude of closures increases sharply toward Ramona, where well-balanced misclosures in loops east and west of the 1927 Santee to Ramona line (fig. 23) suggest that the Ramona area sustained a relative uplift of about 0.061 m with respect to the Santee/Lakeside area between 1927 and 1938. In addition, the large negative misclosure around the 1927/1938/1939 circuit Ramona-Santa Ysabel-Julian-Tule Springs-Barona Valley-Ramona suggests that Santa Ysabel sustained uplift of about 0.09 m with respect to Ramona between 1927 and 1938/1939 (fig. 23). These arguments, accordingly, imply cumulative net uplift at Santa Ysabel of 0.10-0.15 m between 1927 and 1938/1939, which is clearly reflected in the three alternative height reconstructions for Santa Ysabel based on levelings via the Miramar/Poway/Ramona area. The first 1938 Santa Ysabel height of 909.6524 m is developed from 1927/1938 levelings that follow a route most closely coincident with subsequent 1955, 1968/1970 and 1978 levelings through the Miramar/Poway area to Ramona, coupled with a local 1927 tie in the Ramona area, and 1938/1939 levelings via Barona Valley, Tule Springs and Julian into Santa Ysabel. The other two 1938 heights of 909.6782 and 909.6837 m are based on similar survey routes with minor differences in routes through metropolitan San Diego (see Appendix Tables J7-J9).

Comparison among the various 1938/1939 heights for Santa Ysabel via both Campo and Miramar clearly shows that a substantial net uplift had developed at Santa Ysabel by the late 1930's, although the magnitude of this uplift could range from as little as 0.05 m to as much as 0.17 m (fig. 18). The discrepancy between any pair of the various Campo- and Miramar-based height values is effectively a measure of the misclosure around the temporally constrained 1938/1939 circuit San Diego-Miramar-Santa Ysabel-Julian-Pine Valley-Campo-San Diego. Most of these values, which range between 0.01 m and 0.10 m (compare with fig. 22), fall within the estimated one-standard deviation limit for levelings of this vintage and order(s) (table 1). In order to simplify the 1938/1939 Salton Trough reconstructions, 1938/1939 heights are based on a single, averaged 1938 starting height at Santa Ysabel of +909.6475 m, which is the arithmetic mean of these eight heights associated with standard deviation of ±0.0476 m.

The 1939 heights for several representative Salton Trough localities, including Salton City (fig. 24), Mecca (fig. 9) and Rockwood (fig. 13) are each based on 1939 levelings leading directly into the Salton Trough via Truckhaven from the averaged 1938 starting height at Santa Ysabel. Because comparisons of 1950 first-order levelings against 1939 second-order surveys south and southeast from Mecca (pls. 3 and 7) disclose little differential movement along their respective lengths, a representative 1939 height for Indio (fig. 8) is based on 1939 levelings into Mecca coupled with a 1950 tie between Mecca and Indio.

Alternative 1939 heights for representative Imperial Valley bench marks at El Centro (fig. 14) and Niland (fig. 16) are based on the results of either 1931 or 1941 levelings from Rockwood, coupled with an appropriate assumption of invariance at Rockwood during the period 1931-1939 or 1939-1941, respectively. In order to avoid mixing the results of pre- and post-1940 earthquake levelings in the Imperial Valley, these reconstructions are based on the 1931 leveling. Nevertheless, circuit closures based on repeated levelings suggest little apparent differential movement locally around the Imperial Valley circuit between 1931 and 1941 (fig. 17). The discrepancy between the results of 1931 and 1941 Rockwood to El Centro levelings is only 0.0115 m and from Rockwood to Niland 0.0070 m (NGS lines L-222 and L-9173). Other evidence based on circuit closures computed from a variety of both temporally-constrained and unconstrained levelings in the Campo-Jacumba-Ocotillo area (pl. 8) suggest that the well-defined 1930's uplift at Campo must have persisted into and across the Imperial Valley. Few of these many closures reveal any significant differential tilting between Campo and Ocotillo during any period from about 1927 through 1978. Moreover, the results of many repeated levelings across the Imperial Valley (pls. 4 and 9) show little evidence of end-to-end tilting between Ocotillo and Ogilby and, hence, imply that the 1930's uplift extended across the width of the Salton Trough. The 1931/1933-1971/1972 comparison from the Imperial Valley to Palo Verde (pl. 5) probably provides the clearest indication that the uplift declined eastward toward the lower Colorado River area (see also Gilmore and Castle, 1983b). Important implications of these results are not only that this uplift broadly transcended traditionally recognized physiographic province boundaries, but that the steepest contemporary tilting must lie well west of the Salton Trough in a relatively aseismic region of the Peninsular Ranges, a deformation pattern also apparent from comparisons of levelings repeated during the 1940's and the 1970's.

1940's. Relatively few levelings were completed in southeastern California during the 1940's and early 1950's (pl. 1). Levelings completed in 1941 following the M=7.1 Imperial Valley earthquake in May 1940 are tied to only local, allegedly "stable bedrock marks" along the margins of the Salton Trough and thus their regional significance remains imperfectly understood. The only other levelings completed during this period consist of several discontinuous second-order lines in the southern Peninsular Ranges and across the western margin of the Salton Trough, which cannot be tied directly to the San Diego reference mark and can only be related to each other indirectly. Nonetheless, a tentative reconstruction of the regional deformation during the 1940's can be developed from results based on successive circuit misclosures, comparative profiles, and extrapolation into intervening areas. These reconstructions clearly suggest that partial collapse of the 1930's uplift in southeastern California was regionally widespread by 1944; however, the timing of this collapse with respect to the 1940 earthquake remains imprecisely determined.

Indirect but important conclusions regarding the nature of regional movement during the 1940's can be derived from comparisons with scattered 1944 relevelings in parts of the Peninsular Ranges. Although it is tempting to postulate significant collapse of the regionally widespread 1930's uplift throughout southeastern California accompanying the 1940 Imperial Valley earthquake, there are only indirect indications of this possibility. Probably the clearest constraint on the nature and timing of the late 1930's-early 1940's collapse is based on a comparison of 1938 and 1944 levelings between Lakeside and Descanso (fig. 25), which clearly demonstrates a steep down-to-the-east tilt in excess of

0.15 m across the western Peninsular Ranges eastward from Lakeside. Even though the 1944 leveling cannot be tied directly to the San Diego reference mark, comparisons of successive levelings in the Lakeside area (pl. 2b) and consideration of the generally small circuit closures in the 1927/1938 network between San Diego and Lakeside (fig. 23) suggest that Lakeside sustained no measurably significant displacement by 1938 with respect to San Diego. A second comparison of 1944 leveling against a 1938 datum extending eastward from Tule Springs, about 10 km southeast of Ramona, to Descanso (figs. 23 and 26) suggests a similar displacement pattern. Although little is known about the vertical displacement history of the Tule Springs area, consideration of 1927/1938 misclosures in this area (fig. 23) indicates that Tule Springs probably sustained at least modest uplift by 1938. In any case, the magnitude of the 1938-1944 signals developed along both these converging routes is about the same, although their respective configurations are somewhat different (compare figs. 25 and 26).

Additional clues to the nature and timing of the presumably postearthquake collapse along the western margins of the Salton Trough can be obtained from comparisons with a partial 1944 releveling of the Julian-Truckhaven line. Comparison between 1939 and 1944 levelings over this reach (pl. 6b) shows that virtually the entire 0.07-m down-to-the-east tilt that had occurred by 1944 was confined to within about 20 km of the Truckhaven area. This pronounced tilt developed abruptly east of the San Jacinto fault zone, whereas the height differences between bench marks west of the San Jacinto remained unchanged during this period. Down-to-the-east tilting continued to develop after 1944 but by 1955/1956 it was more or less uniformly distributed along the entire length of this line (pl. 6b). Successive circuit misclosures in the Ocotillo Wells-Truckhaven area based on various combinations of 1939, 1944 and 1955/1956 levelings (fig. 27) suggest that the most significant tilting in this area occurred between 1939 and 1944 and that little differential movement occurred during the subsequent 1944-1955/1956 period. Thus analogous to the preceding 1930's uplift, the propagation of collapse across the Peninsular Ranges and Salton Trough was complex and irregular in both space and time. Nevertheless, the timing of the late 1930's-early 1940's regional collapse can be provisionally reconstructed by assuming that the partial collapse recognized in the western Peninsular Ranges (see above) extended at least as far east as the beginning of the 1944 survey into Truckhaven, about 12 km east of Julian (pl. 1). Based on this assumption, partial collapse along the flanks of the preearthquake uplift had developed across the western Peninsular Ranges by no later than 1944, forming a particularly pronounced tilt west of the Salton Sea. Although little additional movement probably occurred within the western Peninsular Ranges after 1944, down-to-the-east tilting continued to increase along the western margins of the Salton Trough through 1955/1956 and apparently involved the intervening central Peninsular Ranges as well.

1955/1956. Levelings completed during the mid-1950's comprise the first regionally widespread levelings in the Salton Trough following the 1940 Imperial Valley earthquake and consist primarily of 1955/1956 first-order ties between San Diego and the Salton Trough (pl. 1), supplemented by a 1955 second-order network in the southern Peninsular Ranges (fig. 28). Widespread regional collapse of the 1930's uplift to approximately 1927 levels was well-defined throughout both the Salton Trough and Peninsular Ranges by no later than the mid-1950's. Many areas nonetheless retained some residual net uplift and a few were characterized by modest cumulative collapse. The mid-1950's probably represent a period of relative regional tectonic quiescence or stability based on the generally small magnitude of 1955/1956 and associated but less tightly constrained circuit closures (figs. 28 and 29; compare especially with fig. 23). Because large-scale collapse of this area certainly may have occurred about the time of the 1940 earthquake, this postulated period of relative quiescence may have begun a decade or more prior to the completion of the 1955/1956 levelings. Several alternative 1955/1956 heights can easily be established for representative bench marks in the Peninsular Ranges and in the central Salton Trough; 1955/1956 heights for various Imperial Valley marks depend on more involved reconstructions.

Representative 1955/1956 heights for bench marks in both the Peninsular Ranges and Salton Trough developed from various alternative routes are generally well-constrained. The 1955 Campo height (fig. 15) is based on first- and second-order levelings via San Ysidro, Dulzura, and Barrett Junction, along a route also common to both the 1938 and 1968/1970 levelings in this area (pl. 1). Two alternative 1955 heights are shown for Santa Ysabel (fig. 18), the one of 909.5238 m based on first-order leveling along the route of the 1927 survey via La Mesa, Lakeside, and Ramona and the other of 909.4999 m on first- and second-order levelings along a more northerly route via Miramar, Poway, and Ramona coincident with that followed by the 1938 and subsequent 1968/1970/1971 and 1978 levelings. Salton Trough vertical displacement profiles based on the results of 1955/1956 surveys (pls. 3, 6 and 7) depend on the 1956 Miramar-based starting height at Santa Ysabel. The two separate Santa Ysabel heights, which differ by less than 0.027 m, provide the basis to directly establish 1955 and 1956 heights, respectively, at several representative Salton Trough bench marks from 1956 leveling via Truckhaven, including Salton City (fig. 24), Mecca (fig. 9) and Indio (fig. 8). Additional alternative 1955 and 1956 heights have been reconstructed for Indio (fig. 8) and Mecca (fig. 9) based on the same Miramar- and La Mesa-based 1955 starting heights at Santa Ysabel, respectively, coupled with 1927 leveling between Santa Ysabel and Aguanga and 1955 leveling from Aguanga to Indio (pl. 1). These alternative reconstructions assume that no differential movement occurred between Santa Ysabel and Aguanga between 1927 and 1955, an assumption supported by the modest misclosure around the 1927/1955/1956 circuit Santa Ysabel-Aguanga-Indio-Mecca-Truckhaven-Julian-Santa Ysabel (fig. 29).

Reconstructed mid-1950's heights at Mecca are complicated by significant differential movement between nearby bench marks in downtown Mecca through which ties between early 20th-century and later levelings must be made (table 4). Differential movement in the Mecca area, and specifically between bench marks -189T, G516, and K572, has generally been attributed to bench mark instability (R.O. Castle and M.R. Elliott, oral communication, 1983). Alternatively, the abrupt differential offsets at these and other nearby bench marks in the Mecca area (table 4) may represent real tectonic movement. However, the nature and timing of this movement are equivocal owing to the limited levelings in this area and because each of these levelings generally does not include all of the bench marks in question. For example, bench mark -189T, the oldest Mecca mark, was not recovered after 1956 whereas bench mark G516, the Mecca tie used in later levelings, was established just before the 1956 leveling. These two marks also can be indirectly related through ties to nearby bench mark K572, about 1 km west of -189T and G516. However, successively determined height differences between bench marks -189T and K572 (table 4) indicate that this height difference remained virtually unchanged between 1939 and 1950, but decreased abruptly by almost 0.1 m between 1950 and 1956. A comparison of 1950 leveling in the Mecca area against the next earliest 1939 or 1928 datums (pls. 7 and 3, respectively) shows that only a very small uniform tilt had developed along the length of these comparisons by 1950. In any case, by 1956 differential movement was well-defined not only between G516 and K572 but between numerous other bench marks in the Mecca area as well (pl. 3).

Because of the complex nature of the vertical displacement field near Mecca, the vertical displacement history for bench mark K572 (fig. 30) has also been reconstructed for comparison with that of G516 (fig. 9). The principal difference between the respective histories at Mecca (compare figs. 9 and 30) is in the differing nature of the movement that occurred between 1938/1939 and 1955/1956 (table 4). However, subtle differences between these two vertical displacement records, particularly during the post-1956 period, suggest that these movements are of a tectonic nature. Thus, although both of these Mecca reconstructions may err in detail, the overall historic trends of vertical displacement patterns near Mecca are still quite similar.

Levelings completed during the mid-1950's do not extend fully around the Salton Sea and hence directly into the Imperial Valley, but two independent 1955/1956 heights can nevertheless be established with reasonable confidence for several representative Imperial Valley bench marks. The best constrained values (shown as 1956) depend on 1955/1956 levelings into Truckhaven, via Miramar, Santa Ysabel and Julian, and 1939 leveling between Truckhaven and Rockwood (fig. 13), along with 1941 surveys between Rockwood and El Centro (fig. 14) and Niland (fig. 16). Circuit misclosures in a modest Imperial Valley network developed from the results of third-order 1955 levelings (USGS summary books PV254 and PV270) against earlier 1939 and/or 1941 datums (fig. 31) are generally small. Even though these circuits do not provide a continuous check along the entire length of the 1939/1941 levelings, the small closures strongly suggest that these earlier levelings may be considered as approximately equivalent to those that would have been obtained in 1955. The one important exception is the 1941/1955 circuit Imperial-Brawley-Orita-Sandia-Imperial, tranversed by the Imperial fault zone (fig. 31), where the large positive misclosure is consistent with continuing and significant down-to-the-north tilting between 1941 and 1955. In contrast, the 1941/1955 circuit El Centro-Imperial-Sandia-Holtville-El Centro to the immediate south (fig. 31), which is also sliced by the Imperial fault, was characterized by a trivial misclosure. Although this value is somewhat below the one standard deviation level of the random error estimate for this circuit (±0.0339 m) and opposite in sign from the above circuit, its sense, geometry and timing are still consistent with a small component of down-to-the-north tilting. Therefore, the results of the 1941 leveling between Rockwood and El Centro used in establishing the 1956 El Centro height of -12.1250 m (fig. 14) have been corrected to a 1955-equivalent by accommodating the 0.0689-m increase in the apparent height difference across the Imperial fault within this reach between 1941 and 1955 (fig. 31).

An alternative and independent reconstruction of mid-1950's heights for several representative Imperial Valley bench marks can be based on 1955 first- and second-order levelings into Campo via San Ysidro, Dulzura (fig. 15), and north to Pine Valley, coupled with 1939 second-order leveling from Pine Valley to Jacumba and 1941 first-order levelings into the Imperial Valley via Ocotillo and El Centro (fig. 14). Alternative 1955 heights of -49.0607 m for Rockwood (fig. 13) and of -52.3801 m for Niland (fig. 16) are also based on these same results, coupled with 1941 leveling northward from El Centro, corrected, as above, to a 1955-equivalent by accommodating the 0.0689-m 1941-1955 postseismic collapse across the Imperial fault. These 1955 values may be associated with a relatively lower degree of certainty owing to necessary but unverifiable assumptions of invariance at the junction marks with the earlier preearthquake levelings. Consideration of 1955 and associated misclosures in the Campo-Pine Valley-Ocotillo area (pl. 8) demonstrates little if any tilting between Campo and Ocotillo during the period 1939-1968. However, comparative profiles involving both pre- and postearthquake levelings in this area (pl. 6c) suggest at least some tilting between Pine Valley and Ocotillo. Regardless, these independently developed, even if indirect mid-1950's Imperial Valley heights generally fall within the estimated random error limit for these levelings and clearly show that by the mid-1950's regional collapse of the 1930's uplift was widespread throughout the Salton Trough and southeastern California.

1968/1969. Reconstructions based primarily on 1968/1969 levelings, some of which were actually completed as late as early 1971, are comparatively straightforward. These levelings form an extensive network throughout the Peninsular Ranges and the northern Salton Trough (fig. 32), but do not extend eastward or southward into the Imperial Valley. Misclosures are generally small throughout this network, in spite of the nearly 3-yr period required for the completion of these levelings. These misclosures, coupled with little other indication of any significant regional tectonic activity, suggest that the Salton Trough remained relatively quiescent from the mid-1950's through at least the late 1960's. Localized vertical displacements occurred during the period 1955/1956-1968/1969 in the general epicentral region of the April 1968 Borrego Mountain earthquake (M=6.4), but they can only be presumed to be coseismic.

As could be inferred from the late 1960's misclosures (fig. 32), alternative 1968/1969 heights developed from any of a variety of routes are quite well-constrained. The three independent heights reconstructed for Santa Ysabel (fig. 18) illustrate this point especially well. The 1969 Santa Ysabel height of 909.5429 m, based on 1968 leveling between San Diego and Miramar and 1970/1971 leveling between Miramar via Poway and Ramona into Santa Ysabel, and defined here as the primary route, provides the basis for the Salton Trough reconstructions (pls. 3, 6, 7 and 10), chiefly because this route is coincident with the primary 1955/1956 and 1978 levelings into Santa Ysabel. Reconstructions of representative 1968 heights for bench marks at Salton City (fig. 24), Mecca (figs. 9 and 30), Indio (fig. 8) and White Water (fig. 7) are based on the results of 1968/1969 levelings via Julian and Borrego from this primary 1969 starting height at Santa Ysabel (fig. 18). The alternative (1969) heights of 345.0587 m and -4.2199 m shown for both White Water (fig. 7) and Indio (fig. 8), respectively, are each based on the results of 1968/1969 levelings from San Diego via Oceanside, San Juan Capistrano, Santa Ana, Riverside, Colton, and Banning (pl. 1). This alternative route is coincident with (at least south of Riverside) in the 1931/1932 route into these bench marks.

Even though a significant pulse of uplift had spread across the Transverse Ranges including the San Bernardino Mountains by the late 1960's (Castle and others, 1984, figs. 60 and 61), it had apparently not propagated southward into either the Peninsular Ranges or the Salton Trough by as late as 1968/1969. Nonetheless, the southwestern Peninsular Ranges had sustained a modest net uplift by the late 1960's, in the form of a relatively uniform, up-to-the-east tilt (pl. 2c). The 1968/1969 heights of representative Coachella Valley bench marks remained essentially unchanged with respect to the latest preceding datums (figs. 7-9). However, a number of bench marks near the Salton Sea sustained modest collapse by 1968/1969 (pls. 6 and 7). A marked relative increase from the previous rate of down-to-the-southeast tilting had developed in this area by 1967 and is independently corroborated by differenced lake-level measurements between stations at opposite ends of the Salton Sea (Wilson and Wood, 1980, p. 185). Comparison of successive levelings athwart the southern San Jacinto fault zone that ruptured during the April 1968 Borrego Mountain earthquake (table 5) shows that this height difference (i.e., the vertical offset across the fault) has increased progressively through time. The most significant tilting clearly developed between the 1956 and 1968/1969 levelings (fig. 33)—a period bracketing the occurrence of the Borrego Mountain earthquake—and is of almost identical magnitude to the cumulative tilt defined by Salton Sea lake-level measurements during this same period (Wilson and Wood, 1980, fig. 2). Although tilting across the San Jacinto fault zone has probably been more or less continuous (pl. 6b), fuller characterization of the timing and distribution of tilting during the 1955/1956-1968/1969 period is precluded due to a change in the leveling route between 1956 and 1968/1969 (fig. 33).

1971/1972. Levelings completed in 1971/1972 form the first complete set of relevelings of primary vertical control lines along and across the Imperial Valley since the 1941 postearthquake surveys. The first-order control surveys are supplemented by a substantial network of second-order levelings within the Imperial Valley (fig. 34). However, like the 1941 surveys, the 1971/1972 levelings in the Imperial Vallev are spatially isolated and cannot be tied directly to either San Diego or other stable control points. Nonetheless, there are several indirect indications that these 1971/1972 Imperial Vallev levelings may be treated as essentially equivalent to 1968/1969 levelings to the northwest. Reconstructions of 1972 heights for representative Imperial Vallev bench marks can be based on either 1927/1933 or 1981/1982 levelings from Hassavampa to Palo Verde via Salome and Blythe and 1971/1972 levelings into the Imperial Valley. These heights depend on an assessment of the vertical displacement record of the Palo Verde area, near the Colorado River (fig. 1), which can only be approximated (see below). Nonetheless, these tentative reconstructions otherwise provide the only available constraint on both the timing and overall magnitude of the apparently rapidly developed mid-1970's uplift throughout southeastern California.

There are several suggestions that relative tectonic quiescence persisted in the Imperial Valley region through about 1971/1972. The small magnitude of late 1960's misclosures throughout the Peninsular Ranges/Salton Trough network based on levelings completed over a 3-yr period through early 1971 (fig. 32) argues that relative inactivitv probably characterized much of southeastern California during this period. This inference is independently supported by repeated lake-level measurements in the Salton Sea which show little overall differential movement during the late 1960's and early 1970's (Wilson and Wood, 1980, fig. 2). Even though down-to-the-southeast tilting along the Salton Sea abruptly accelerated during the late 1960's with respect to earlier trends, the rate of tilting apparently slowed by about 1970 or 1971 and had reversed to a down-to-the-northwest tilt by late 1972. Thus by 1972, the cumulative down-to-the-southeast tilt developed along the axis of the Salton Sea between about 1968 and 1970 had been more or less erased (Wilson and Wood, 1980, p. 184).

The nature and magnitude of any movement between Mecca and Niland from 1968 to 1972 can be no more than approximated. Extrapolation of the trends defined by the 1976 and 1978 levelings against both the 1968/1969 datum in the Coachella Vallev and the 1971/1972 datum in the Imperial Valley (pl. 10) suggests that little differential movement could have occurred between 1968 and 1972 in the intervening segment along the Salton Sea and hence also in the Imperial Vallev. The trend defined by the 1976-1978 comparison between Mecca and Niland (pl. 10), when compared to an extrapolated 1968/1972 datum over this reach, accounts for virtually all of the apparent difference between the 1968-1976 (or 1978) signal at Mecca and the 1972-1976 (or 1978) signal at Niland.

Because the 1972 Imperial Valley network cannot be tied directly to either the San Diego reference mark or invariant southwestern Arizona bench marks, 1972 Imperial Valley heights have been based on reconstructions of the relative movement history of the Palo Verde area. Both anomalous circuit closure values and the representative height reconstructions developed below suggest that this area has probably sustained modest net uplift during the 1927-1982 period of record. Several heights have been reconstructed for representative bench marks at both Palo Verde and Blythe (table 6) based on the onlv available combinations of relevelings in this area, which were completed in 1927/1933, 1931/1933 and 1981/1982 (pl. 1). These limited comparisons indicate Palo Verde probablv sustained a cumulative uplift of about 0.12 m (or more) between 1927/1933 and 1981/1982. However, the timing of this movement remains unclear. Moreover, the relatively large, 0.1045-m misclosure around the 1972/1981/1982 circuit Ogilby-Blythe-Salome-Hassayampa-Gila Bend-Ogilby (fig. 35) further complicates reconstruction of the vertical displacement record at Palo Verde, indicating that differential movement of about this magnitude must have occurred somewhere (but not where) between Ogilby and Palo Verde between 1972 and 1981/1982.

Therefore, there are two possibilities, representing the extremes of a continuum, for reconstructing 1972 heights for representative Imperial Valley bench marks. First, 1972 Imperial Valley heights can be based on 1981/1982 levelings between Hassayampa and Palo Verde, coupled with an assumption of invariance at Hassayampa (fig. 3b), and 1971/1972 levelings into representative bench marks at El Centro (fig. 14), Rockwood (fig. 13), and Niland (fig. 16). This reconstruction, shown by the solid dots in figs. 13, 14, and 16, implies that Palo Verde sustained a net uplift of some 0.1 m by 1972, and is the interpretation favored in this report. Alternatively, 1972 Imperial Valley heights shown as open circles are based on 1927/1933 levelings between Hassayampa and Palo Verde, coupled with an assumption of invariance at Hassayampa (fig. 3b), and 1971/1972 levelings into El Centro (fig. 14), Rockwood (fig. 13), and Niland (fig. 16). These alternative 1972 Imperial Valley heights assume that Palo Verde remained relatively invariant between 1927/1933 and 1972 (i.e., that most or all of the movement at Palo Verde occurred after 1972). With this alternative interpretation, the magnitude of both cumulative post-1940 earthquake collapse and the uplift at El Centro between 1971/1972 and 1973/1974 would be correspondingly increased about 0.1 m and the magnitude of the signal developed at El Centro between 1971/1972 and 1973/1974 would approach 0.50 m. Even the favored—and notably, the most conservative—interpretation requires that El Centro sustained uplift of nearly 0.40 m during the period 1971/1972-1973/1974. The apparent magnitude of this displacement declines slightly northward toward the Salton Sea area (see also pl. 10), but the total uplift at Niland during this same interval is at least 0.30 m.

1973/1974. Levelings completed during 1973/1974 lead into the Salton Trough only indirectly via a circuitous route through San Pedro, Los Angeles, Mojave, Amboy, Twentynine Palms, and Cottonwood Pass (pl. 1). First-order 1973/1974 levelings extend southward from Mecca along both sides of the Salton Sea and along and across the Imperial Valley, where they are supplemented by a substantial network of second-order levelings (fig. 36). Misclosures in the 1973/1974 Imperial Valley network (fig. 36) are based on observed elevation differences derived from the machine-readable data base, which was the only complete and homogeneous data set available. The results presented for this network are therefore contaminated to some degree by a height-dependent computational error. However, because the maximum elevation difference is only about 116 m throughout this entire network and only about 54 m (75% are 25 m or less) within any individual loop, the inaccuracies thus introduced probably remain small. None of the profiles or vertical displacement histories involving 1973/1974 data anywhere else in this report depend on machine-readable results.

Widespread and pronounced regional uplift was well-developed throughout the Salton Trough during the period 1971/1972-1973/1974, apparently increasing in magnitude southward from about 0.15 m near Mecca to at least 0.40 m at El Centro. Substantial uplift also extended westward into the Peninsular Ranges at least as far as the Pine Valley/Campo area, the westernmost extent of 1973/1974 levelings in this area (pl. 9). The uplift apparently declined rapidly westward toward the coast near San Diego, but its gradient can be inferred only indirectly. Thus both the overall magnitude and areal extent of the mid-1970's uplift are strikingly similar to the earlier 1930's uplift in southeastern California, but there are important differences as well. For example, uplift during the mid-1970's in the Salton Trough region is more or less contemporaneous with widespread regional uplift in the Transverse Ranges and throughout other parts of southern California (Castle and others, 1984). However, the 1930's uplift in southeastern California appears to have been more spatially distinct, although it probably closely followed a similar early 20th-century regional uplift in southern California (Castle and others, 1986).

As indicated in an earlier section (see "Errors in height determinations"), parts of both the 1973/1974 and 1976 levelings leading into the Imperial Valley mav have been contaminated by a magnetic-deflection error identified with the Ni1 automatic level. This error would be disclosed as a pronounced, azimuth-dependent, down-to-the-north artifactual tilt when compared against otherwise error-free levelings. The 1973/1974 levelings between Amboy and El Centro are most apt to have been affected by this potential error source because the average azimuth of this route is approximately parallel to magnetic north in this area. However, height changes based on a comparison of the results of the 1973/1974 surveys against 1978 levelings along this reach show no significant overall differential tilting (Burford and Gilmore, 1984, fig. 5). Moreover, the results of 1973/1975 levelings originating at mean sea-level in San Francisco and based on the same four Ni1 instruments used between Amboy and El Centro[1/], close almost perfectly on mean sea-level at San Pedro. This observation is consistent with the virtually flat sea-surface topography between these points inferred from both oceanographic (steric) measurements and earlier spirit levelings (Castle and Elliott, 1982, table 3). Since these results argue that the automatic levels used in both the San Francisco and San Pedro levelings were free of any magnetic-deflection error, it follows that any earlier surveys based on these same instruments (such as the 1973/1974 Amboy-El Centro levelings) were equally free of this error.

Because the 1973/1974 levelings along the coast extend from San Pedro south only to about San Onofre (San Diego County line), the 1973/1974 tie between San Diego and San Pedro is based on the results of 1968/1969 levelings (table 2) corrected to a 1973/1974-equivalent by accommodating the known rate of uplift of the San Pedro tide station with respect to San Diego (Castle and Elliott, 1982, figs. 9 and 16). During this approximately 6-yr period, uplift at San Pedro relative to San Diego was about 0.0094 m (1.56 mm/yr x 6 yr). Thus, the 1968/1969 height difference between San Diego and San Pedro has been decreased by this amount in order to establish the 1973/1974-equivalent starting height at San Pedro.

From this computed 1973/1974-equivalent starting height at San Pedro, a 1974 height has been reconstructed for each representative Mecca bench mark (figs. 9 and 30) based on 1973/1974 levelings via Los Angeles, Saugus, Palmdale, Mojave, Barstow, Amboy, Twentynine Palms, and Cottonwood Pass. Alternative 1973/1974 heights can be established through either representative bench mark at Mecca (figs. 9 and 30) for representative Imperial Valley bench marks from levelings along both sides of the Salton Sea (fig. 36). Levelings completed in 1973/1974 along the northeast side of the Salton Sea, the more frequently releveled and identified here as the primary route, provide the basis for establishing 1974 heights at Niland (fig. 16), Rockwood (fig. 13) and El Centro (fig. 14). Other alternative 1974 heights can also be reconstructed based on the results of 1973/1974 levelings along the west side of the Salton Sea via Salton City (fig. 24) into Rockwood (fig. 13), Niland (fig. 16), and El Centro (fig. 14). The anomalously large misclosure around the 1973/1974 Salton Sea circuit (fig. 36), a measure of the discrepancy between these two alternative 1974 heights, is probably attributable to intrasurvey deformation in this area. Such movement is especially likely during the extended period required for the completion of this circuit; the seven separate 1973/1974

[1/]A comparison of the instrument identification numbers shows that all of the Ni1 automatic levels (78300, 90829, 90834 and 90856) used in the 1973/1974 Amboy-El Centro levelings (NGS lines L-23243 and L-23315) were also used in one or more of the various lines involving authomatic levels that define the 1973/1975 San Francisco-San Pedro survey (specificallv, NGS lines L-23297, L-23596, L-23599, L-23611, L-23644, L-23760, L-23781 and L-23784).

survey segments that comprise this circuit were actually completed over a period of about 15 months (12/1973-2/75; NGS lines L-23243, L-23315, L-23343, L-23349, L-23361, L-23501, and L-23712).

Levelings completed during 1973/1974 also extend across the Imperial Vallev from El Centro (pl. 10) and westward as far as Pine Valley, and hence provide a basis to at least indirectly assess the nature of the mid-1970's uplift in this part of the southern Peninsular Ranges. An indirect 1974 height can be established for Campo (fig. 15) based on the results of these 1973/1974 levelings into Pine Valley, coupled with a 1968/1970 tie into Campo. Assuming that no significant differential movement occurred over the approximately 15-km reach from Pine Valley to Campo between 1968 and 1974 (pl. 8), this reconstruction shows that maximum uplift in the Campo area by 1974 probably did not exceed 0.25 m.

1976. Although levelings in southeastern California completed during 1976/1977 are of only limited extent, they provide control along virtually the entire axis of the Salton Trough and across the Imperial Valley (pl. 1). All of the 1976 heights for Salton Trough bench marks are reconstructed with respect to the average starting height for the Bill Williams River reference mark in southwestern Arizona (fig. 3a); none of the 1976 levelings emanated directly from San Diego. Regardless, the results of these reconstructions provide important clues to the nature and timing of partial collapse of the mid-1970's uplift throughout southeastern California

Representative 1976 heights for representative Salton Trough bench marks are based on 1976 levelings emanating from the Bill Williams River via Freda Junction, Desert Center, and Cottonwood Pass into Mecca (pl. 1 and figs. 9 and 30). From a tie at Mecca, 1976 heights can also be established for Indio (fig. 8) and White Water (fig. 7) based on the results of 1976 and 1976/1977 levelings into Imperial Valley bench marks at Niland (fig. 16), Rockwood (fig. 13) and El Centro (fig. 14).

Although reconstructed 1976 heights for several representative northern Salton Trough bench marks demonstrate some modest residual uplift with respect to earlier datums (no 1973/1974 levelings are available northwest of Mecca), little end-to-end differential tilting has developed along the axis of the Coachella Valley during the post-1956 period (pl. 10). On the other hand, profiles involving 1976 levelings both along and across the Imperial Valley (pls. 9 and 10) disclose pronounced tilting with respect to both earlier and later 1970's datums. The maximum mid-1970's uplift developed at Mecca in 1974 had almost completely collapsed by 1976 (figs. 9 and 30). Uplift apparently persisted somewhat longer and attained a greater magnitude southward into the Imperial Valley, where it is defined by a steepening, up-to-the-southwest tilt south of the Imperial fault toward El Centro (pl. 10). The pronounced up-to-the-west tilting in the 1976 profile across the Imperial Valley toward Ocotillo (pl. 9) implies that significant uplift probably persisted through at least 1976 in parts of the southern Peninsular Ranges as well.

1978. The relatively widespread 1978 levelings in southeastern California (fig. 35) were completed as part of the 1978 Southern California Releveling Program (Burford and Gilmore, 1984). Most misclosures based on the rapidly completed 1978 levelings are generally small throughout this network (fig. 35), even though there may have been intrasurvey tectonic movements in adjoining parts of the Transverse Ranges (Burford and Gilmore, 1984, table 1). Representative 1978 heights for Salton Trough bench marks are based on levelings leading directly from San Diego via Miramar and Julian into the Salton Trough at either El Centro or Mecca. For comparative purposes, alternative 1978 heights also have been developed along an indirect route via San Pedro, Mojave and Amboy coincident with that of the 1973/1974 levelings. Regardless of which of these alternative 1978 heights are selected, the range in the resulting heights is remarkably narrow. Comparative profiles based on these results show that regional collapse of the mid-1970's uplift to approximately preuplift values throughout the Salton Trough and Peninsular Ranges was more or less complete by 1978. The anomalous differential tilting developed within and across the Imperial Valley by 1976 (pls. 9 and 10) had almost completely disappeared or reversed by 1978. In contrast, little or no differential displacement apparently occurred within the northern Salton Trough, reflecting a general continuation of the post-1956 trends in this area (compare pls. 3 and 10).

The 1978 heights for various Salton Trough bench marks are based on 1978 levelings extending eastward from San Diego via Miramar, Poway, and Ramona into Santa Ysabel (fig. 18) and Julian. Two separate levelings lead into the Salton Trough from Julian, one southeast via Pine Valley and Ocotillo into El Centro and the other directly east and northeast into Mecca via Salton City (fig. 24). These two reconstructions provide the basis for alternative 1978 heights at White Water (fig. 7), Indio (fig. 8), Mecca (figs. 9 and 30), Niland (fig. 16), Rockwood (fig. 13), and El Centro (fig. 14). Profiles of 1978 levelings against earlier Salton Trough datums (pls. 3, 4, 6, 7, 9 and 10) are based on 1978 levelings via Miramar, Julian, and Pine Valley into El Centro.

A third set of alternative and independent 1978 heights has been developed for representative bench marks at Mecca and within the Imperial Valley. These heights are based on the results of 1978 levelings along a route coincident with that of the circuitous 1973/1974 levelings via San Pedro, Mojave and Amboy (pl. 1). However, results of the 1978 leveling along the coastal reach between Miramar and Newport Beach are considered suspect (Castle and Elliott, 1982, p. 7005-7012; Burford and Gilmore, 1984, p. 7). The presumed distortion identified in the 1978 survey probably is a result of intrasurvey movement, but could be due as well to local bench mark disturbance or instrumental error (Burford and Gilmore, 1984, p. 9-11). Moreover, the 0.10-m discrepancy between the 1968/1969 and 1978 coastal levelings between Miramar and Newport Beach (Castle and Elliott, 1982, p. 7008) is approximately balanced by a compensating error along the 1978 Newport Beach-Riverside segment (Burford and Gilmore, 1984), resulting in the deceptively small and seemingly inconsequential misclosure around the 1978 circuit Newport Beach-Riverside-White Water-Mecca-Julian-Miramar-Newport Beach (fig. 35). In order to avoid utilization of these suspect surveys, the 1978 height difference between San Diego and San Pedro included in this alternative reconstruction has again been based on the results of 1968/1969 levelings (table 2) converted to a 1978-equivalent based on the known rate of uplift of the San Pedro tide station relative to San Diego (1.56 mm/yr x 10 yr = 0.0156 m). Based on this computed 1978-equivalent starting height at San Pedro, ties to representative Salton Trough bench marks can be derived from the results of 1978 levelings via Los Angeles, Saugus, Palmdale, Mojave, Barstow, Amboy, Twentynine Palms, and Cottonwood Pass into Mecca (figs. 9 and 30), Niland (fig. 16), Rockwood (fig. 13), and El Centro (fig. 14).

A representative 1978 height for Campo (fig. 15), based primarily on 1978 leveling, can be developed from the results of 1978 leveling between San Diego and Pine Valley, via Miramar, Santa Ysabel, and Julian, coupled with 1968/1970 leveling from Pine Valley and Campo and an assumption of invariance over this reach between 1968/1970 and 1978. Indirect comparisons based on the results of 1968/1970 and 1978 levelings in adjoining areas (pl. 6 and fig. 18) suggest that little overall differential change occurred in this general area during this period. Moreover, a comparison of the results of 1973/1974 levelings between Pine Valley and at least Ocotillo (pl. 9) shows no significant differential movement in this area, in spite of the intervening development of significant regional uplift and subsequent collapse between 1968 and 1978. An earlier representation of the 1973/1974-1978 collapse across this area (Burford and Gilmore, 1984, fig. 5) errs in placing the steepest gradient of tilting east of its actual position. The results of this study suggest instead that the zone of steepest tilting probably lies well to the west of where it was previously shown near Campo (Burford and Gilmore, 1984, figs. 5 and 6). Further north in the Peninsular Ranges, where the height changes are better constrained, the northern Peninsular Ranges probably sustained progressively less collapse northward and an abrupt increase in the 1973/1974-1978 collapse gradient in this area may have developed across the San Jacinto fault zone.

1981. Levelings completed during 1981/1982 are concentrated in southwestern Arizona (pl. 1) and provide important ties to 1978 relevelings in southeastern California at several places (fig. 35). The limited distribution of these levelings provides no more than an indirect basis for establishing a 1981 (post-1979 earthquake) El Centro height, but it does allow for a more detailed assessment of the overall nature and easternmost extent of contemporary crustal movement east of the Salton Trough. The 1981 El Centro height (fig. 14) is based on the results of the 1981 leveling from Hassayampa via Yuma to El Centro (pl. 1), coupled with an assumption of invariance at the Hassayampa reference mark with respect to San Diego (see section on "Reference Mark"). A limited comparison of 1978 and 1981 levelings crossing the Imperial fault between El Centro and Holtville (fig. 5) suggests that this area sustained little differential movement, in spite of the intervening M6.5 Imperial Valley earthquake in October 1979 and extensive associated surface rupture along the Imperial fault. Nevertheless, this area was probably characterized by a net regional subsidence of about 0.03 m with respect to a tectonically invariant datum during this earthquake-bracketing period (fig. 3b). A comparison of the 1981 leveling with other previous and more complete datums across the Imperial Valley (pl. 9) shows little evidence of any significant movement within this reach, except locally across the Imperial fault.

Comparisons among the results of 1981/1982 levelings and the few existing earlier datums in southwestern Arizona (pl. 11) indicate that contemporary crustal movement has extended well into this otherwise virtually aseismic region, although the timing of these movements is uncertain. The cumulative 1927-1981 trend in this area indicates that the eastern Imperial Valley sustained about 0.1 m of uplift during this period (pl. 11, compare with pl. 4), but the vertical displacements decline in magnitude and probably also in areal extent over a short distance east of the Colorado River as several rather abruptly defined steps.

It is unclear whether apparent offsets near Yuma and east of Wellton flanking the Gila Mountains may be fault-related or when they may have developed. Although contemporary tectonic movements are virtually absent in southwestern Arizona east of the Gila Mountains, the effects of compaction-induced subsidence within this area are disclosed by pronounced, localized depression of the vertical-displacement field in the Gila Bend area (pl. 11). Significant groundwater pumping for irrigation has been underway near Gila Bend since 1951 (small-scale groundwater extraction actually began in this area as early as 1935, but did not involve significant withdrawals until the early 1950's; Sebenik, 1981, sheets 2 and 4) and probably in the Dateland area as well, where groundwater withdrawls accelerated during the late 1960's (White and others, 1979, sheet 2). Because significant groundwater withdrawls in the Gila Bend/Theba area have been almost entirely restricted to the post-1951 period, most or all of the apparent 1927-1981 subsidence at Gila Bend with respect to Hassayampa (pl. 11) probably dates chiefly from that time. Hydrographs showing changing water levels for selected wells in this area (Sebenik, 1981, sheet 4) suggest that some areas have sustained cumulative groundwater level declines of 30 m or more, with the most rapid decline during the 1950's and 1960's and a minor but incomplete period of recovery (i.e., water-level rise) due to aquifer recharge during the relatively wetter 1970's. Hence, the 1981 heights with respect to a

1952 datum extending between Wellton and Gila Bend (pl. 11) are attributable to the apparent 0.0655-m compaction-induced subsidence of the Gila Bend starting bench mark (A14)inferred to have developed almost entirely during this period.

DISCUSSION AND INTERPRETATION

The vertical displacements described in the preceding reconstructions provide the basis for a brief interpretive characterization of progressive changes in the vertical-displacement field of the Salton Trough and adjoining parts of southeastern California during the 20th-century. These interpretations are presented as generalized profiles showing the historic trends of vertical movement both along the axis of the Salton Trough from around San Gorgonio Pass to the International border (fig. 37a) and transversely across the Imperial Valley near the latitude of El Centro (fig. 37b). While these interpretive characterizations probably accurately represent the overall regional extent, approximate magnitude, and changing configuration of historic vertical movements in the Salton Trough, some of these reconstructions almost certainly err in detail. Moreover, owing to the wide variation and distribution of leveling data in both space and time in southeastern California, the displacement history in places is necessarily extrapolated. Nonetheless, considered as an integrated whole, these reconstructions form a coherent and consistent characterization of overall historic movement patterns in the Salton Trough region. In any case, the results of this investigation are believed to have important implications for understanding not only the complex contemporary tectonics within the Salton Trough but those along the rapidly evolving plate margin as well.

General pattern of contemporary vertical crustal deformation in southeastern California. Comparisons among the results of repeated geodetic levelings in the Salton Trough suggest both considerable variability and complexity in vertical displacement patterns throughout southeastern California, even during the relatively short, approximately 80-year span of the historic record. Regional patterns of vertical crustal deformation in the Salton Trough have changed markedly through both space and time and variously involve periods of relative tectonic quiescence, abrupt episodes of accelerated aseismic tilting, and periodic reversals in tilt direction. The vertical-displacement histories of a number of selected bench marks are characterized by long-term trends consistent with those recognized in the latest Quaternary geologic record. Regional geodetic trends define a net structural deepening in the Salton Sea area; but most other areas, including both the Coachella Valley and the Imperial Valley, have sustained significant net uplift during the period of historic record. Moreover, contemporary crustal movement in southeastern California actually extends broadly beyond the Salton Trough and involves considerable historic movement and tilting within a relatively aseismic portion of the southern Peninsular Ranges extending nearly as far west as metropolitan San Diego. The magnitude of cumulative uplift declines rapidly east of the Colorado River, but persists into southwestern Arizona as relatively irregular arching as far east as the Gila Mountains, about 70 km east of Yuma. Disregarding compaction-induced subsidence, no significant vertical displacements have been recognized from the Gila Mountains eastward to Hassayampa, an observation consistent with both the general absence of historic seismicity and the geologically inferred stability of this part of southwestern Arizona.

In many places, particularly in the Imperial Valley, the long-term geodetic trend has been periodically or cyclically punctuated by abrupt and rapidly developed, short-term pulses of uplift and subsequent partial collapse, specifically during the 1930's and again in the 1970's. The overall gross similarities in both the timing and character of these pulses, which are regionally widespread and range in magnitude up to at least 0.4 m, argue that they are somehow related to elastic strain accumulated in advance of relatively large earthquakes on the Imperial fault in 1940 and 1979. A similar but more localized episode of accelerated surface tilting may have preceded the 1968 Borrego Mountain earthquake within the epicentral region of this shock west of the Salton Sea.

Trends of historic vertical displacement patterns within the Salton Trough. Detailed examination of geodetically-defined vertical displacement trends demonstrates considerable variation in both the nature and the magnitude of historic movement in different parts of the Salton Trough. For example, most of the northern Salton Trough and northern Peninsular Ranges show a cumulative historic trend characterized by a pronounced up-to-the-northwest tilt and modified by significant differential warping, (fig. 37a). The largest signals recognized here occurred in the northern Coachella Valley immediately southeast of White Water between the early 1900's and the early 1930's and have persisted into the late 1970's. This area, flanked by the rapidly uplifted San Jacinto Mountains to the southwest and Little San Bernardino Mountains to the northeast, sustained net uplift exceeding 0.6 m during the period 1902-1978 (fig. 7). Net uplift actually declines northwestwardly toward the topographic crest at San Gorgonio Pass, which has probably sustained cumulative uplift of about 0.4 m (pl. 3; see also Castle and others, 1985, fig. 32). Although vertical control in the northern Salton Trough is virtually nonexistent for the period 1931-1968/1969, an important transition must have developed in this area by 1968/1969. A pronounced pulse of uplift had occurred at Colton and in other parts of southern California by 1968/1969 (Castle and others, 1984, figs. 35 and 60), but no anomalous tilting occurred at either White Water (fig. 7) or Indio (fig. 8) by this time, and areas near the Salton Sea continued to subside (figs. 9, 24 and 30). Both the northern Salton Trough and the Imperial Valley had certainly sustained major, broadly defined regional uplift by 1973/1974, but the southward propagation of uplift probably developed after 1971 or 1972 (see also Wilson and Wood, 1980, fig. 2).

During the early 20th-century, a similar delay occurred in this same general area accompanying development of an earlier regional uplift. Pronounced uplift developed in parts of southern California including Colton as early as 1906 and spread well into the northern Salton Trough and northern Peninsular Ranges by the mid-late 1920's (Castle and others, 1986, figs. 28-32), but it apparently did not affect the southern Peninsular Ranges and the Imperial Valley prior to the early 1930's or conceivably as late as about 1935. The implication of both these later and earlier patterns is that significant surges of crustal swelling have repeatedly migrated southward along hundreds of kilometers of the southern California plate margin as spasmodic bursts or pulses. Moreover, both of these recognized surges developed over very short time frames and each seemed to hang up or pause near the frontal fault system flanking the southern Transverse Ranges and bordering the northern Salton Trough.

Probably the steepest tilt gradient recognized within the Salton Trough developed over the 22-km reach between Indio and Mecca (table 7 and fig. 38). Whereas Indio has sustained net uplift in excess of 0.25 m (fig. 8), Mecca has sustained equally significant—or even greater—cumulative tectonic subsidence (figs. 9 and 30). Thus the total relative height difference between Indio and Mecca (about 50 m) has actually increased by about 0.5 m during the period of historic record, implying development of a pronounced local tilt gradient. In fact, even though this height difference has increased more or less progressively through time (table 7), much of the increase developed in a relatively short period of greatly accelerated tilting during the early 20th-century. The tilt is otherwise quite uniform, and a hinge or inflection point characterized by little or no differential historic change occurs almost exactly halfway between Indio and Mecca near bench mark P70 (pl. 3).

Most of the Salton Sea area, including Mecca (figs. 9 and 30) and Salton City (fig. 24), are characterized by cumulative net subsidence. Both Mecca and Salton City sustained similar net subsidence of about 0.25-0.30 m, but tilting has developed much more rapidly at Salton City (compare figs. 9 and 24). Results of these geodetic comparisons, coupled with trends derived from Salton Sea lake-level measurements (Wilson and Wood, 1980, fig. 2), demonstrate both significant historic tilting and rapid tilt reversals within the Salton basin and imply that the locus of maximum contemporary subsidence has shifted or migrated locally within this area. Maximum subsidence is centered in both the vicinity of Mecca and the northernmost Salton Sea and near the southern end of the Salton Sea, perhaps along the Brawley seismic zone or concentrated near local geothermal areas (see especially pl. 7).

Significant contemporary vertical movement also has characterized the northeastern margin of the Salton Trough, apparently extending well into the southern Mojave Desert. The most complete record in this area is based on five repeated levelings into a representative bench mark at Fargo Junction (fig. 39, table 8), about 15 km northeast of Indio. Fargo Junction has sustained cumulative net uplift in excess of 0.2 m during the limited period of record, although total movement during the period 1931-1978 has actually exceeded 0.3 m.

A similar but much steeper trend occurs between Mecca and Cottonwood Pass (fig. 40), about 35 km northeast of Mecca (pl. 1). Comparisons among these results indicate that the Cottonwood Pass area has sustained historic net uplift in excess of 0.40 m with respect to an invariant San Diego reference mark. Owing to the likelihood of significant intrasurvey deformation during the course of the 1931 leveling, the maximum cumulative range of vertical movement at this mark probably actually approaches 0.6 m (Castle and others, 1984, p. 82-85, 89-93; see "Detailed Geodetic Reconstructions," this report). In any case, a very steep, up-to-the-northeast tilt has developed progressively between Mecca and Cottonwood Pass during the 20th-century which, in conjunction with the similar trend between Indio and Fargo Junction, suggests that this area northeast of the San Andreas fault zone has been uplifted more rapidly than the adjacent lowlands to the southwest (see also Castle and others, 1984, fig. 64; Burford and Gilmore, 1984, fig. 7).

A third rather limited comparison (in both space and time) is based on successive 1970's levelings between Frink and Frink Quarry (pl. 1 and table 9). All of these comparisons, at least qualitatively, indicate that regional deformation during the especially active 1970's must have extended well across the northeastern margin of the trough near Frink as well.

Finally, the more detailed vertical displacement record at Niland (fig. 16) is seemingly more consistent with the overall history of other bench marks near the San Andreas along the trough's northeastern margin than the record of other Imperial Valley-proper bench marks. Even though this mark lies southwest of (although very close to) the San Andreas fault zone in this area, its history more closely resembles that within a broad belt straddling the San Andreas fault elsewhere. Thus ranges flanking the northeastern margin of the Salton Trough have sustained differentially greater relative uplift than adjoining parts of the Coachella Valley to the southwest. Moreover, movement patterns commonly do not change abruptly at or across major bordering fault zones, but temporal shifts in historic activity levels and/or rate or direction of tilting are apparent in profiles crossing both the San Andreas (pls. 3 and 10) and San Jacinto (pl. 6 and table 5) fault zones. Each fault has sustained both seismic and aseismic displacements and each has also periodically served as a principal hinge axis of contemporary tilting or oscillating vertical movement (pls. 3 and 6; see also Burford and Gilmore, 1984, fig. 5). At other times, however, contemporary regional deformation has extended broadly beyond these faults as if no major active structure were present.

Contemporary crustal deformation within the Imperial Valley is particularly widespread, complex, and variable. Its historic trend may be only generally characterized as a progressively increasing, up-to-the-south tilt extending along the structural axis of the trough from the southern end of the Salton Sea toward El Centro and the International border (fig. 37a). However, the regional trend within the Imperial Valley is complicated by local crustal deformation associated with continuing movement along the Imperial, Brawley, and other subparallel active faults (pls. 9 and 10). The most dominant tectonic feature in the Salton Trough is a broad belt of progressively increasing crustal deformation associated with continuing activity along the Imperial fault which extends for at least 20 km to the west and perhaps 30 km or more north and east of El Centro (pl. 9). Results of several repeated levelings (fig. 5 and pl. 9) suggest that the especially broad deformational zone extending eastward to at least Holtville may consist of several other subparallel fault strands, although their relation to the Imperial fault remains unclear. Following the 1979 Imperial Valley earthquake, a small block was locally downdropped east of the Imperial fault, forming a small graben (fig. 5). This block may be bounded on its eastern margin by the Rico fault, which was first recognized after it ruptured during the 1979 earthquake (Sharp and others, 1982, p. 142). Nonetheless, there seems to be little significant tilting locally across the fault zone or the full width of the Imperial Valley (fig. 37b). Net uplift in the El Centro area is about 0.15-0.20 m and net regional uplift of similar, or perhaps even slightly greater, magnitude persists westward to at least Ocotillo and probably well into the Peninsular Ranges. Moreover, a similar pattern extends well east of the Imperial fault, where the net uplift gradually declines to about 0.10-0.12 m toward Ogilby.

Other comparisons of repeated levelings in the Imperial Valley more clearly define a down-to-the-north tilt extending northward from El Centro, especially across a broad zone where the leveling route somewhat obliquely crosses right-stepping, en echelon breaks at the northernmost end of the Imperial fault near Brawley (pl. 10). Further north, the character of the vertical displacements athwart the Brawley seismic zone is somewhat more irregular. Although considerably smaller in overall magnitude and area affected than the Imperial fault, progressively increasing and relatively widespread surface deformation is also associated with several other Imperial Valley faults. Examples include the Brawley and Calipatria (?) faults (pl. 10), an unnamed but previously recognized fault near Dixieland, known to have sustained repeated creep or distant fault-triggered offsets (pls. 4 and 9), and the Algodones (?) fault (pl. 11). Both the overall down-to-the-north Imperial Valley tilt and a subtle but clearly defined downwarping across the valley (pls. 4 and 9) are consistent with the continuing, progressive enlargement of pull-apart basins between successive, right-stepping, right-lateral faults northward toward the Salton Sea (Aydin and Nur, 1982, p. 100-103). In addition to deep-seated crustal rifting, this downwarping probably also reflects some component of compaction-induced subsidence within the thickening and spreading sedimentary prism. Moreover, some evidence indicates that the Imperial Valley—and perhaps including many fringing areas—has behaved periodically as a more or less tectonically coherent unit sustaining relatively simple (?) vertical, but oscillating, block movement. This is best demonstrated by the generally small Imperial Valley misclosures involving various combinations of early 20th-century levelings (figs. 6 and 17) and by the general lack of tilting across the width of the trough during virtually the entire period of historic records (pls. 4 and 9).

The nature of contemporary deformation patterns across the Salton Trough between San Diego and southwestern Arizona (fig. 37b) can only be characterized in a generalized way owing to the rather fragmentary available comparisons. Although the vertical-displacement history of only a couple of selected parts of the southern Peninsular Ranges have been examined in any detail, there appears to have been little overall net historic movement in the Santa Ysabel area (fig. 18). However, other parts of the southern Peninsular Ranges probably have sustained cumulative uplift and westward tilting, including Campo (fig. 15). The early 1900's Campo values seemingly plot about 0.3 m (1 ft) above the otherwise clear trend of progressive net uplift defined by 1927 and later reconstructions (fig. 15). However, there is no evidence of a bust in these results anywhere between San Diego and Campo based on limited comparisons with subsequent levelings. The nature of crustal activity near Campo during the period 1901-1927 is uncertain, and a more complete explanation for this seeming anomaly remains equivocal. In any case, net uplift in the Campo area since 1927 probably has been about 0.10 m and has accumulated relatively uniformly through time, even though this trend has been punctuated by periodic spasms of regionally widespread movement. A uniform but much more subtle contemporary uplift extends broadly across all of southeastern California, from the southern Peninsular Ranges across the Imperial Valley, where it probably peaks near El Centro (pls. 4 and 9), and then gradually declines beyond the Colorado River (fig. 37b). This persistent and progressively increasing historic uplift may reflect regional crustal swelling due to thermal expansion in the upper crust associated with deep-seated rifting, magmatic intrusion, and anomalously high regional heat flow (see especially Elders and others, 1972, fig. 5).

In summary, not only have significant differential vertical displacements occurred within the Salton Trough, but contemporary movement has extended regionally well beyond the Salton Trough, broadly straddling the tectonically active plate margin throughout southeastern California. Seismically active areas, such as the Imperial Valley, have been characterized by some of the largest oscillatory vertical displacements recognized in this report, but flanking, largely aseismic regions in both the southern Peninsular Ranges and the southwestern corner of Arizona also have sustained surprisingly widespread though much more subtly defined historic displacements. The magnitude of differential displacements developed along the axis of the Salton Trough is especially impressive. For example, during the approximately 80-yr historic record, the cumulative height difference over the 90-km reach between Mecca and White Water has increased by nearly 1.0 m. Moreover, the 40-m height difference over the 125-km reach between Mecca and El Centro also has increased by about 0.5 m during this same period.

Relations to the latest Quaternary geologic record. Geodetically defined vertical displacement trends in the Salton Trough reflect an apparent continuation of deformational trends recognized in the latest Quaternary geologic record. Historic vertical displacement patterns are also generally consistent with other indices of contemporary deformation, including repeated regional triangulation surveys (Elder and others, 1972; Thatcher, 1979) and Salton Sea differenced lake-level measurements (Wilson and Wood, 1980). Long-term geodetically defined uplift rates around the Salton Trough, compare quite favorably with independently based geologic studies of average late Quaternary uplift rates (Castle and others, 1984, p. 122). These measurements have been derived from such diverse geologic analyses as emergence rates of marine terraces along coastal southern California (Lajoie and others, 1979; McCrory and Lajoie, 1979), fault offset studies (Sharp, 1981), correlation and comparisons of reconstructed equilibrium snowline altitudes of successive latest Pleistocene glacial advances on San Gorgonio Mountain with those of other alpine glacial records (Herd, 1980, p. 15-16) and comparisons of long-term historic mean sea-level changes between adjacent coastal California tide stations (Castle and Elliott, 1982). However, it is the uniformitarian implications of the very short-term (especially from a geologic-time perspective), episodic and/or oscillatory nature of contemporary movement so apparent throughout the historic geodetic record in this area that may be most important to eventually understanding the nature of the longer-term tectonic processes that characterize this particularly complex and possibly unique plate margin. A major remaining problem is to provide a clearer explanation of the relation (assuming there is one) of such short-term historic processes and patterns to the longer-term geologic development of this tectonically molded region. It is increasingly clear that various tectonic processes are active—or interactive—over vastly different time scales, but what generally remains preserved in the geologic record is often only the cumulative result: whether the nature of the process has been relatively continuous and gradual or characterized by abrupt or especially oscillatory movement (or some complex combination) is simply obscured or otherwise indeterminant. A useful conceptual analogy might be considered by avoiding strict application of the traditional Davisian or Darwinian notion of the uniformly gradual and progressive nature of uniformitarianism. Instead, the original concept may be modified to one of a "punctuated uniformitarianism" (to extend Stephen Jay Gould's concept of punctuated equilibria), whereby long-term, more gradual geologic or tectonic processes are periodically or even cyclically punctuated by major environmental, or in this case seismic, catastrophies (see also Elders and others, 1972, p. 20).

Preliminary comparison of vertical displacement patterns with distribution of contemporary seismicity and occurrence of major historic earthquakes. In general, there is a relatively poor correlation between the distribution of contemporary seismicity in the Salton Trough (Hileman and others, 1973, fig. 55; Johnson and Hill, 1982, fig. 7), and historic vertical displacement patterns. The purpose here is to point out several of the most evident relations between the vertical displacement record and the historic earthquake record. Despite the high level of historic faulting and earthquake activity, much of the tectonic movement within the Salton Trough, and throughout southeastern California in general, is decidedly aseismic. Such movement is distinguished primarily by its relatively broad spatial distribution with respect to that of contemporary seismicity and by its rapid, widespread development and spasmodic migration. Some of the most pronounced or steepest geodetically defined tilts have developed in such conspicuously aseismic regions as the lower Coachella Valley/northern Salton Sea area and flanking northeastern margin across this historically aseismic section of the San Andreas fault zone (Hileman and others, 1973, fig. 55) and the southern Peninsular Ranges. Moreover, the broad regional distribution of crustal activity in southeastern California is more clearly correlated with the almost equally broad area of anomalously high regional heat flow in the Salton Trough region (Lachenbruch and others, 1985). They have interpreted these patterns to represent distribution of deep-seated tectonic rifting into much broader zones of crustal extension within the relatively thick continental crust of this rifting environment in order to balance regional heat flow with present crustal structure and composition. Contemporary deformation in the Salton Trough is characterized by both seismic and aseismic movement and "there is no evidence to conclude other than that seismicity and the apparently aseismic deformation are equally valid (or complementary) expressions of the orogenic process. (Moreover,) simply because we are unable to show that one is somehow directly derivative from the other does not preclude an ultimately demonstrable relation between the two" (Castle and others, 1984, p. 123).

Certainly one of the most fascinating and potentially important patterns revealed among these comparisons is the close temporal association between significant changes in regional vertical displacement patterns and the subsequent occurrence of several relatively large-magnitude historic earthquakes in the Imperial Valley. Similar periods of rapidly accelerating but essentially aseismic regional uplift apparently preceded both the May 1940 M7.1 and October 1979 M6.5 Imperial Valley earthquakes near El Centro during much of the decade prior to each event. These regionally widespread pulses seem to be correlated with these large-magnitude Imperial Valley earthquakes based on the general similarities in the approximate magnitude, overall areal extent and relative timing of regional uplift in southeastern California during both the 1930's and 1970's. Moreover, both pulses propagated generally southward, although at slightly differing rates, and perhaps most significantly, the maximum signal developed during both cycles is centered in the El Centro area, approximately straddling the Imperial fault.

Other geodetic evidence of historic fault activity. Significant vertical displacements have occurred along or across not only the seismically active Imperial and southern San Jacinto fault zones and other active Imperial Valley faults, but also across several other previously mapped faults, otherwise unknown to have sustained historic movement. Most of the movements described in this section are considerably smaller in both magnitude and areal extent than those associated with more active faults. Nonetheless, their individual displacement characters are quite variable, with some showing relatively continuous movement while others are characterized by more abrupt and temporally constrained offsets.

A sharply defined, approximately 0.05-m, up-to-the-east offset developed athwart the La Nacion fault near San Ysidro between 1927 and 1938 (pl. 2c). However, this narrowly defined offset does not appear to have been associated with any of the very few nearby and small-magnitude earthquakes occurring within this period (Hileman and others, 1973, figs. 5-11; Real and others, 1978) and has apparently remained unchanged since 1938. Several small-magnitude displacements immediately north of San Diego in Rose Canyon (pl. 2a) suggest contemporary activity along the Rose Canyon fault zone in this area (Ziony and others, 1974, sheet 2).

In contrast, comparisons among repeated levelings across the San Andreas fault zone northeast of the Salton Sea both northwest and southeast of Frink (pls. 3, 4 and 10) show that movement there has been more continuous and has increased progressively through time (see especially pl. 10), deforming a progressively broadening zone on each side of the fault. These comparisons are also consistent with the vertical displacement records at both Fargo Junction (fig. 39) and Cottonwood Pass (fig. 40) in showing a substantial relative uplift of the area northeast of the San Andreas fault zone (pl. 3). While this section of the San Andreas has been generally aseismic during historic time (Hileman and others, 1973, fig. 55), local areas periodically have sustained measureably significant displacements triggered by distant earthquakes (Allen and others, 1972; Sieh, 1982). Geodetic results in this same area show that the cumulative vertical offset across the fault between 1928 and 1978 exceeds 0.10 m (pl. 3).

Progressively increasing displacements also occur across other faults in the Imperial Valley, including an unnamed fault near Dixieland (pls. 4 and 9). An anomalously large, somewhat broadly defined and progressively increasing downwarp developed sometime between 1939 and 1974 near Westmorland (pl. 7). It is unclear when this movement occurred and whether it is fault-related, associated with local geothermal development (fig. 1) or reflects more broadly distributed tectonic deformation associated with the Brawley seismic zone or some complex combination of these processes.

Other subtly defined but still abrupt vertical offsets, especially in the Peninsular Ranges, may also be associated with contemporary faulting although their timing or potential correlation with earthquake activity have not been determined. Contemporary displacements have apparently occurred along several previously mapped faults not otherwise known to have sustained Quaternary movement (Jennings, 1975; see also fig. 1), including faults about 10 km southwest of Santa Ysabel (pl. 2b), between Santa Ysabel and Julian (pl. 6), in the Ramona/Poway Valley area (pl. 2a), in the San Ysidro Mountains about 10 km east of San Ysidro (pl. 2c), and possibly also between Descanso and Pine Valley and near Jacumba (pl. 6).

In addition, abruptly defined, active fault-like movement has also been recognized several places where no known faults have previously been mapped (Jennings, 1975; Wilson and others, 1969). The progressively increasing offset at and adjacent to bench mark Z572, about 25 km south of Mecca (pl. 7), is probably the best constrained such example. Although movement at Z572 has also been attributed to either local bench mark disturbance or instability (Wilson and Wood, 1980, p. 184; Castle and others, 1984), these more detailed comparisons against successively younger datums (pl. 7) suggest that such movement is actually tectonic. Not only has bench mark Z572 sustained considerable overall differential subsidence with respect to nearby bench marks, but marks immediately adjacent to Z572, especially to the southeast, also show progressively increasing degrees of more subtly defined relative movement as a function of proximity to bench mark Z572. The relative offset at Z572, which has been recovered in each successive survey, has increased progressively and more or less uniformly through time. This trend can be clearly tracked in these profiles where the local offset is greatest against the earliest datums and gradually decreases in magnitude until there is no apparent local differential offset at Z572 (or other adjacent bench marks) between 1974 and 1978. Although this pattern is typical of continuing deformation along other well-recognized active fault zones (see, for example, pls. 4-7, 9, and 10), no known recently active faults (?) have been mapped in this area (Jennings, 1975).

Geodetic evidence of apparent active faulting also marks the diffuse eastern margin of the Salton Trough over a wide region extending well into southwestern Arizona, although the timing of movements in this area is rather poorly constrained (pl. 11). Offsets probably have occurred along the Algodones and/or Sand Hills (?) faults in southeastern California, along an inferred fault near Yuma and possibly as far east as inferred range front faults (?) flanking the Gila Mountains in southwestern Arizona. These important indications of potential historic activity may provide reasonable starting points for future detailed geologic mapping or studies of contemporary tectonics.

Relation to the southern California uplift and implications for regional tectonics. The correspondence in timing, magnitude, areal extent and continuation of widespread regional uplift extending throughout the Salton Trough and southeastern California during the 1970's with that in other parts of southern California implies that the original characterization of the overall distribution and extent of the southern California uplift by Castle and others (1984) must be considered as incomplete. Not only is the southern California uplift far more widespread than previously recognized, broadly straddling the entire plate margin throughout all of southern California, but it extends well south of the International boundary into northern Baja California. Patterns recognized in the vertical control record of southeastern California may have important implications for understanding the nature of contemporary deformation within southern California and larger-scale plate margin tectonic processes in general.

Comparisons among these leveling results indicate that contemporary tectonic activity and movement along much of the southern California plate margin is characterized by a steadily southward, episodic or sporadic migration of abruptly defined pulses of crustal swelling or uplift during periods of accelerated movement. The modern uplift apparently nucleated locally in the western Transverse Ranges near Ozena as early as 1960. By late 1961 or early 1962, regional uplift spread rapidly eastward into the central Transverse Ranges and was approximately centered near the San Gabriel Mountains, straddling the Big Bend region of the San Andreas fault. The uplift then continued to migrate erratically but gradually eastward into the San Bernardino Mountains and other parts of the eastern Transverse Ranges by the late 1960's, but apparently did not extend south of the frontal fault system at this time. By 1974, an additional pulse of activity subsequently and substantially increased both the magnitude and areal distribution of the southern California uplift in and around the Transverse Ranges (Castle and others, 1984). At the same time, regional uplift of comparable magnitude and extent was also widespread throughout southeastern California, but significant movement in the Salton Trough and Peninsular Ranges did not occur until after 1971/1972. At its probable maximum in 1974, the southern California uplift formed a broad belt of crustal swelling about 200 km wide, roughly straddling the plate margin for more than 700 km and encompassing an area of geologically and tectonically diverse terranes well in excess of 100,000 km^2. The maximum uplift ranged from about 0.3-0.5 m over large areas and relatively regularly spaced peaks occurred in the western Transverse Ranges, flanking the San Gabriel Mountains, athwart the San Bernardino/Little San Bernardino Mountains and in the southern Imperial Valley/Colorado River delta region.

These reconstructions also provide additional control on the nature, timing and distribution of the regional collapse which rapidly followed culmination of the southern California uplift during the mid-late 1970's. By 1976, much of the area involved in the southern California uplift in the Transverse Ranges and extending into the Salton Trough as far south as Mecca had sustained at least partial regional collapse, although the timing and distribution of this collapse remains unclear (Castle and others, 1984, p. 116-118). A general southward migration of regional collapse through southeastern California is well documented during the mid-late 1970's by comparing trends among several representative Salton Trough bench marks. The 1974 (maximum) uplift at Mecca had almost completely collapsed by 1976 and little, if any, additional net movement developed in the Mecca area between 1976 and 1978 (figs. 9 and 30). However, the uplift persisted near its maximum level through at least early 1977 further south in the Imperial Valley and in parts of the southern Peninsular Ranges as well. Near Rockwood (fig. 13), some partial collapse had occurred by 1976 but most of the collapse in this area actually developed between 1976 and 1978. The uplift persisted at El Centro (fig. 14) and westward into the southern Peninsular Ranges essentially unchanged at its maximum values through the full period from 1974 through at least early 1977 and then collapsed almost entirely within a year or less between early 1977 and early 1978.

A particularly striking correlation exists between the timing of significant periods of accelerated surface tilting or tilt reversals in the Imperial Valley during the 1970's and large, aseismic creep events on the northern Imperial fault (Goulty and others, 1978). Analyses of both repeated resurveys of alignment arrays and creepmeter records from various Imperial fault crossings (Goulty and others, 1978) suggest that periods of accelerated aseismic creep have occurred episodically along this section of the fault about every 3 years and may have been, but were not necessarily, triggered by dynamic shaking from local earthquakes. Except for the January-April 1968 period when no direct vertical control is available in the Imperial Valley, each of the other three identified periods of accelerated aseismic creep in June-October 1971, September 1973-May 1974 and April 1977 correspond temporally with local tilt reversals in the southern Imperial Valley. A pronounced local increase in the up-to-the-south 1976/1977 tilt gradient between Rockwood and El Centro apparently hinged along this section of the northern Imperial fault, but had completely disappeared by the time of the next releveling in early 1978 (pl. 10). A similar temporal correspondence between significant changes in the vertical displacement record during the late 1970's and associated changes in local gravity and horizontal strain values has been recognized in other parts of southern California (Jachens and others, 1983; Castle and others, 1984). A dramatic reversal in the pattern of regional strain accumulation from one dominated by uniaxial north-south contraction (with little or no significant east-west strain) to one characterized by essentially uniaxial east-west extension occurred in various places between 1977 and 1979 and approximately brackets a simultaneous regional tilt reversal in the vertical displacement record (Burford and Gilmore, 1984). This abrupt change in contemporary deformation patterns may have triggered, or been triggered by, the increase or acceleration of seismic activity in southern California beginning by 1978 or 1979, which included the 1979 Imperial Valley earthquake (Raleigh and others, 1982; Burford and Gilmore, 1984, p. 15, 18).

Based on this analysis, the overall character of the orogenic process in the Salton Trough is thus similar in many respects, although not in detail, to that in other parts of southern California, especially in the Transverse Ranges (Castle and others, 1984, p. 123-131). Contemporary crustal deformation in southeastern California is characterized by both significant coseismic movement and regionally widespread pulses of significant aseismic crustal uplift and partial collapse. The regional distribution and the episodic and/or spasmodic nature of contemporary deformation is presumably related to rapid spreading and intrusive crustal accretion at depth beneath the Imperial Valley and the Colorado River delta. The complex gradation between crustal rifting in the Salton Trough region and rapid uplift and mountain building between anastomosing strike-slip and thrust faults to the northwest is expressed as differential or migrating displacement, uplift, tilting or marginal deformation along these fragmenting crustal blocks. Variations in the style of historic vertical crustal movement in various parts of the Salton Trough may reflect pronounced local changes in the nature of contemporary tectonic relations between adjoining strands of the San Andreas and related faults. For example, the contemporary tectonic framework of the northernmost Salton Trough represents a complex and persisting structural knot and zone of convergence in the modern San Andreas system characterized by the development of successive left-step transfer of contemporary activity (i.e., right-lateral slip) between various segments of the San Andreas and San Jacinto fault zones (Matti and others, 1985). In this strongly compressional tectonic regime, also (and probably not coincidentally) characterized by the highest rates of contemporary uplift (fig. 7 and pl. 3), movement is particularly episodic in nature and a pulse of uplift may be unable to subsequently relax because of continuing convergence. Such conditions may also occur, albeit to a lesser degree, along parts of the San Andreas fault-bounded northeastern margin of the Salton Trough, such as the Cottonwood Pass area (fig. 40). In contrast, displacement patterns in the Imperial Valley and Salton Sea areas, which represent extensional environments, are characterized by considerably more oscillatory movement, where rapidly developed uplift is subsequently followed by a partial collapse. In these spreading regimes, regional uplift may also develop in response to increased regional crustal strain, but then relaxes and resumes its more gradual, long-term geologic trend because of such fundamental differences in its contemporary geologic setting.

The apparently much clearer correlation between the timing of widespread changes in regional vertical displacement patterns and significant fault-related movement in the Salton Trough, including the occurrence of several relatively large earthquakes in the Imperial Valley, may reflect fundamental differences in the geologic and plate margin setting of this area as compared with that of the Transverse Ranges. Whereas the Transverse Ranges are characterized by juxtaposition of geologically diverse rock types and a considerable degree of upper crustal structural complexity, the Salton Trough is distinguished by its very thick, areally extensive and relatively much more homogeneous sedimentary and metasedimentary deposits. Governed by a closer alignment of principal faults with respect to the actual direction of plate motion and the anomalously high geothermal gradients, crustal behavior in the Salton Trough region may be characterized by a considerably greater degree and relative uniformity of internal tectonic mobility. Under such conditions, rapid slip at depth might then be more readily and directly tranferred to the surface as episodic pulses of aseismic crustal uplift and deformation that somehow bear a more direct relation to the earthquake process. Such pulses may abruptly follow periods of relative tectonic quiescence when some threshold value of regional elastic strain buildup has been exceeded or may be associated with fundamental changes in or reversal of earlier regional strain accumulation patterns and may occasionally also result in significant coseismic slip.

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Table 1. Random error estimates for various orders and periods of leveling used in this report, where km = distance in kilometers between bench marks (from Vanicek and others, 1980, p. 507-508).

Order of leveling	Period	Random error estimate (mm)
1st order	before 1917	2.0 mm$\sqrt{km}$
	1917-1955	1.5 mm$\sqrt{km}$
	1956 and later	1.0 mm$\sqrt{km}$
2nd order	1917-1955	3.0 mm$\sqrt{km}$
	1956 and later	2.0 mm$\sqrt{km}$
3rd order	before 1956	6.0 mm$\sqrt{km}$
	1956 and later	4.0 mm$\sqrt{km}$

Table 2. Height differences for bench mark Tidal 8, San Pedro, with respect to bench mark M57, San Diego.

	Observed elevation difference (m)
Based on combination of 1931/1932 and 1932/1933 levelings, corrected for 0.01 m compaction-induced subsidence at Santa Ana during 1-yr junction interval	-2.3594
Based on 1968/1969 levelings	-2.3378
Based on 1931/1932/1933 levelings, as above, corrected to a 1968- equivalent by allowing for 1.56 mm/yr uplift of San Pedro with respect to San Diego.	-2.3594 +0.0562 -2.3032

Data sources: L-386 (1931/1932); L-570 (1932/1933); L-21529, L-21862, L-21596, L-21537, L-21729 (1968/1969); uplift correction from Castle and Elliott (1982, figs. 9 and 16).

Table 3. Sequentially developed observed elevation differences between representative bench mark Y57, near Campo, and nearest early 1900's bench marks immediately to the west (2323) and east (2543) of Campo.

Date of leveling	Order of leveling	Observed elevation difference (m)	
		2323 - Y57	2543 - Y57
1926/1927	1st		-94.7182
1938	3rd	-27.6752	
1955	2nd	-27.7471	-94.7152
1968/1970	1st	-27.7357	-94.7309

Data sources: 82606 (1926/1927); USGS summary books 7802 and 7820 (1938); L-15540.3, L-15540.8 (1955); L-21532 (1968/1970).

Table 4. Sequentially developed observed elevation differences between adjacent bench marks near Mecca.

Date of leveling	Order of leveling	Observed elevation difference (m)			
		-189T - K572	G516 - K572	H516 - K572	G516 - H516
1939	2nd	-0.9019			
1950	1st	-0.9009			
1956	1st	-0.8113	-1.0435	-3.8303	+2.7868
1968/1969	1st		-1.0730	-3.8616	+2.7886
1973/1974	1st		-1.0320	-3.8746	+2.8426
1976	1st		-1.0268	-3.8684	+2.8416
1978	1st		-1.0781		

Data sources: L-8583 (1939); 30th Engineers Survey (1950); L-15875 (1956); L-21770 (1968/1969); L-23315 (1973/1974); L-24071 (1976); L-24301.18, L-24301.19 (1978).

Table 5. Sequentially developed height differences across southern San Jacinto fault zone between bench marks D580, about 28 km east of Julian, and G577, Salton City. Routes of leveling shown in fig. 33; 1939 and 1956 levelings are coincident along southern route via Truckhaven; 1968/1969 and 1978 levelings are coincident along northern route via Borrego.

Date of leveling	Order of leveling	Height difference (m)
1939	2nd	-472.9731
1956	1st	-472.9777
1968/1969	1st	-473.0548
1978	1st	-473.0860

Data sources: L-8582 (1939); L-15872, L-15875 (1956); L-21883 (1968/1969); L-24301.19 (1978).

Table 6. Reconstructed heights for bench marks G134, Palo Verde, and H133r, Blythe, based on various combinations of levelings with respect to southwestern Arizona reference marks

Dates and routes of levelings	Orthometrically corrected height (m)	
	G134, Palo Verde	H133r, Blythe
1927/1933, via Hassayampa, Salome, Quartzsite and Blythe	+169.3485	+75.4490
1931/1933, via Bill Williams River, Parker Dam and Blythe	+169.2385	+75.3390
1981/1982, via Hassayampa, Salome, Quartzsite and Blythe	+169.4707	+75.5455

Data sources: 82625 (1927); L-7407 (1931); L-608, L-653 (1933); L-24555.3, L-24562.2, L-24562.3 (1981/1982).

Table 7. Sequentially developed observed elevation differences between representative bench marks at Indio (-15T, S70) and Mecca (-189T, K572)

Date of leveling	Order of leveling	Observed elevation difference (m)	
		-15T - 189T	S70 - K572
1902	3rd	-53.095	
1928	1st	-53.373	
1950	1st	-53.431	
1956	1st	-53.5626	-48.1509
1968/1969	1st		-48.1226
1976	1st		-48.1354
1978	1st		-48.1520

Data sources: USGS summary book 9488 (1902); L-11 (1928); 30th Engineers Survey (1950); L-15875 (1956); L-21770 (1968/1969); Riverside County line 603-1 (1976); L-24301.18 (1978).

Table 8. Sequentially developed observed elevation differences between bench marks S70, Indio, and 1C, Fargo Junction, and successively developed heights for bench marks S70 and 1C with respect to bench mark M57, San Diego

Date of leveling	Height difference between bench marks S70 and 1C (m)	Orthometric height for S70, Indio, with respect to M57, San Diego (m)	Orthometric height of 1C, Fargo Junction, with respect to M57, San Diego (m)
1931	+248.5966	-10.6153	+237.9813
1939/1950	+248.5893	-10.2030	+238.3863
1956	+248.6762	-10.4456	+238.2306
1968	+248.6158	-10.4429	+238.1729
1978	+248.6047	-10.3989	+238.2058

Data sources: L-7407 (1931); 30th Engineers Survey (1950); L-15875 (1956); L-21773 (1968); L-24301.36 (1978). Primary Indio heights for S70 from Appendix tables D7,D10, D12, D16, D19 and L-15875.

Table 9. Sequentially developed observed elevation differences between Mecca (K572) and Cottonwood Pass (D723) and between Frink (V614) and Frink Quarry (N1230 and R1230)

Date of leveling	Observed elevation difference (m)		
	K572 - D723	V614 - N1230	V614 - R1230
1972		+82.7844	+150.4181
1974	+601.2820	+82.7814	+150.4164
1976	+601.2528	+82.7722	+150.4041
1978	+601.2537	+82.7854	

Data sources: L-22606 (1972); L-23315 (1974); L-24071 (1976); L24301.28 and L-24301.37 (1978).

Table 10. Index to detailed vertical displacement histories for representative southeastern California bench marks referred to in this report

	Bench mark and location	Plotted in text figure	Reconstructed heights and data sources given in tables
A	22Q, Bill Williams River	3a	A1-A4
B	010, Hassayampa	3b	B1-B4
C	1130, White Water	7	C1-C15
D	-15T, Indio	8	D1-D20
E	G516 and K572, Mecca	9 and 30	E1-E19 and 4
F	G577, Salton City	24	F1-F10
G	R69, Niland	16	G1-G10
H	-162Y, Rockwood	13	H1-H15
I	R59, El Centro	14	I1-I16
J	J62, Santa Ysabel	18	J1-J15
K	Y57, near Campo	15	K1-K12
L	2H, Cottonwood Pass	40	L1-L5
	1C, Fargo Junction	39	8

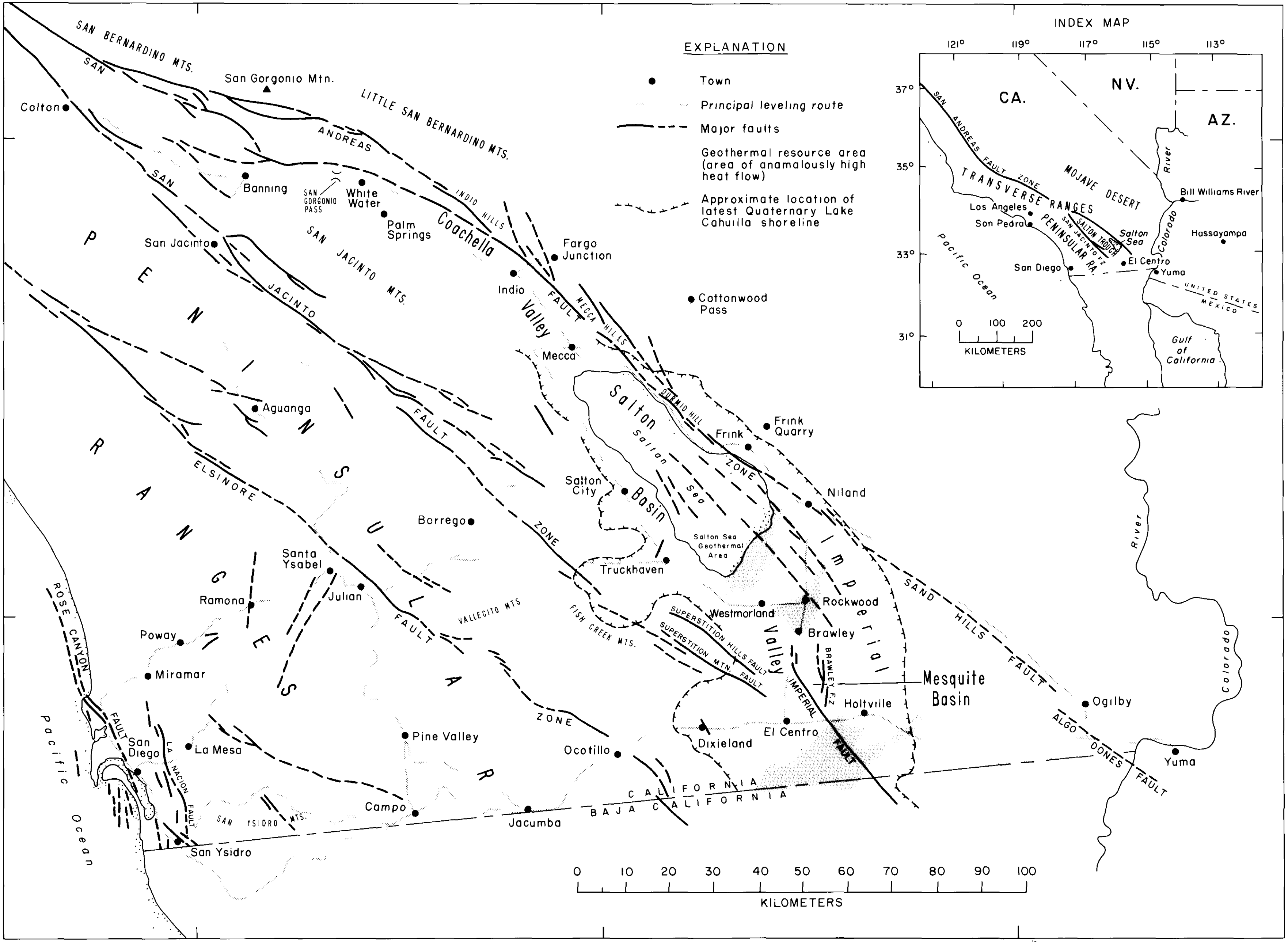


Figure 1. Index map of the Salton Trough region in southeastern California showing major geographic and geologic features and approximate limits of study area. Principal faults identified with known or suspected Quaternary activity from Jennings (1975) and Fuis and others (1982, fig. 24). Approximate locations of principal active geothermal areas (pattern) from Fuis and others (1982, fig. 19) and Elders and others (1972, fig. 2). Late Holocene Lake Cahuilla shoreline from van de Camp (1973, figs. 1 and 2) and Sharp (1982, fig. 4).

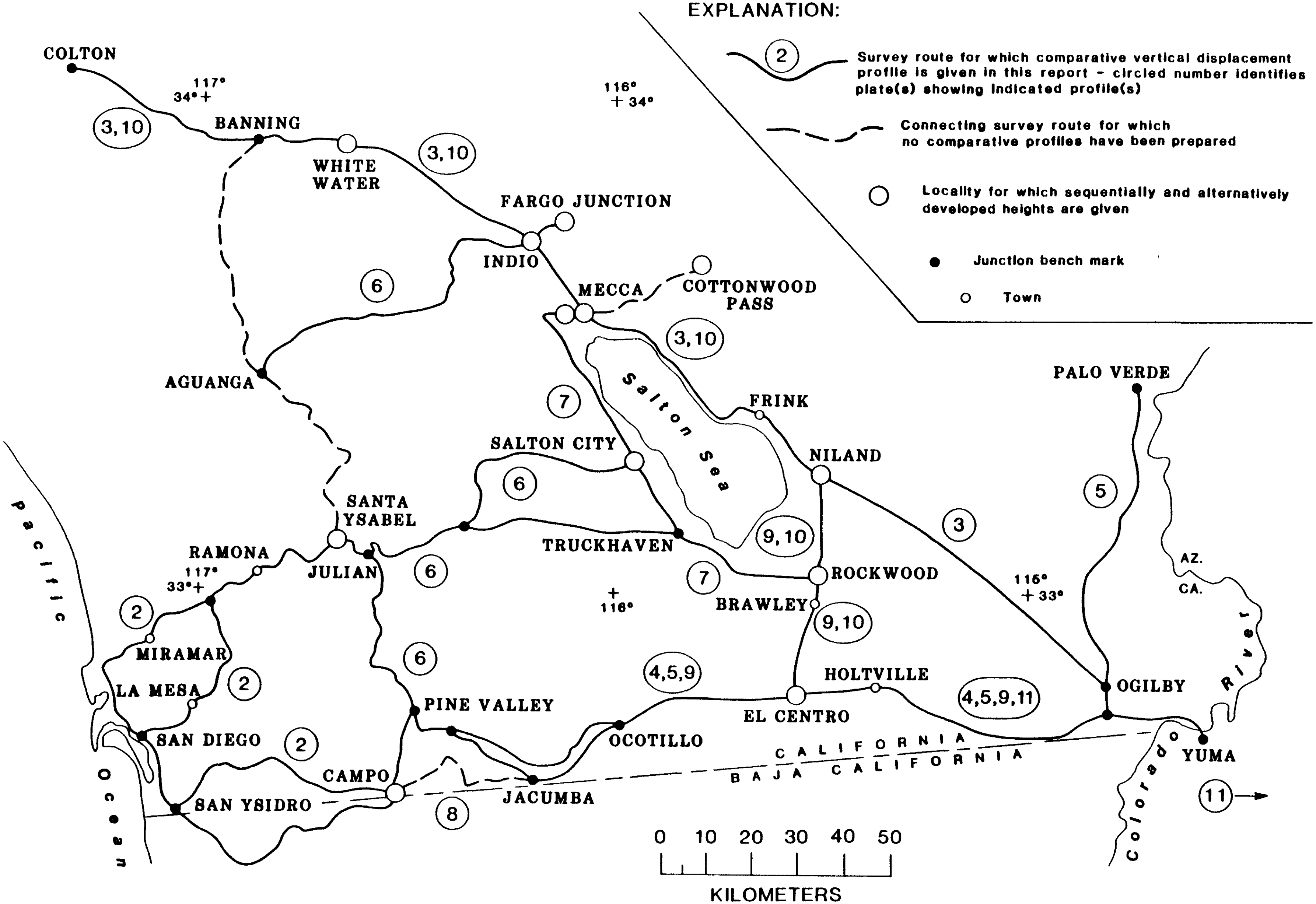
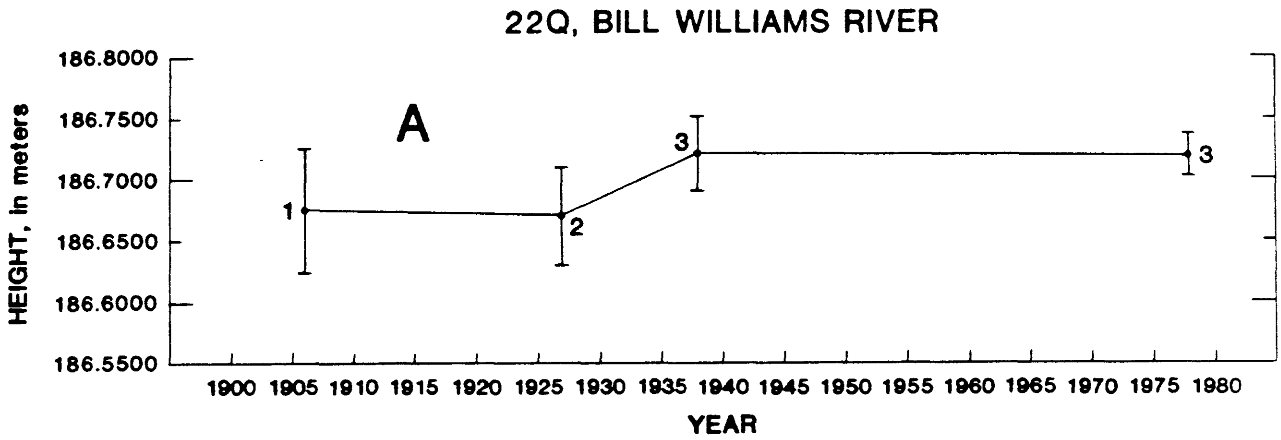


Figure 2. Index map of southeastern California showing principal leveling routes and locations of representative bench marks for which changes in orthometric heights have been developed in detail.



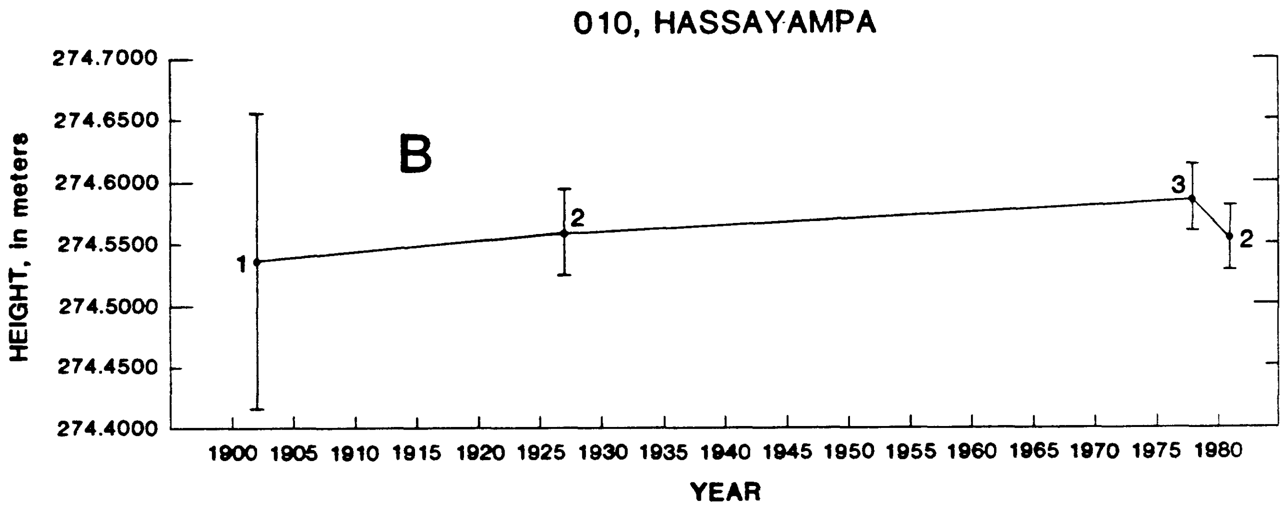


Figure 3. Changes in orthometric heights for representative bench marks in southwestern Arizona, with respect to bench mark M57, San Diego. A Bench mark 22Q, Bill Williams River (about 25 km east of Parker Dam, pl. 1), based on levelings along the following routes:

1 via Santa Ana, Colton, Barstow, Goffs, and Yucca
2 via El Centro, Yuma, Hassayampa, Salome, and Yucca Junction
3 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, and Freda Junction.

Reconstructions outlined in detail in Appendix, Tables A1-A4. B Bench mark 010, Hassayampa (about 50 km north of Gila Bend, pl. 1), based on levelings along the following routes:

1 via San Pedro, Los Angeles, Colton, Mecca, Yuma, and Gila Bend
2 via El Centro, Yuma, and Gila Bend
3 via El Centro, Freda Junction, Bill Williams River, and Salome.

Reconstructions outlined in detail in Appendix, Tables B1-B4. See pl. 1 for bench mark and route locations. Error bars show one standard deviation value for estimated random error only.

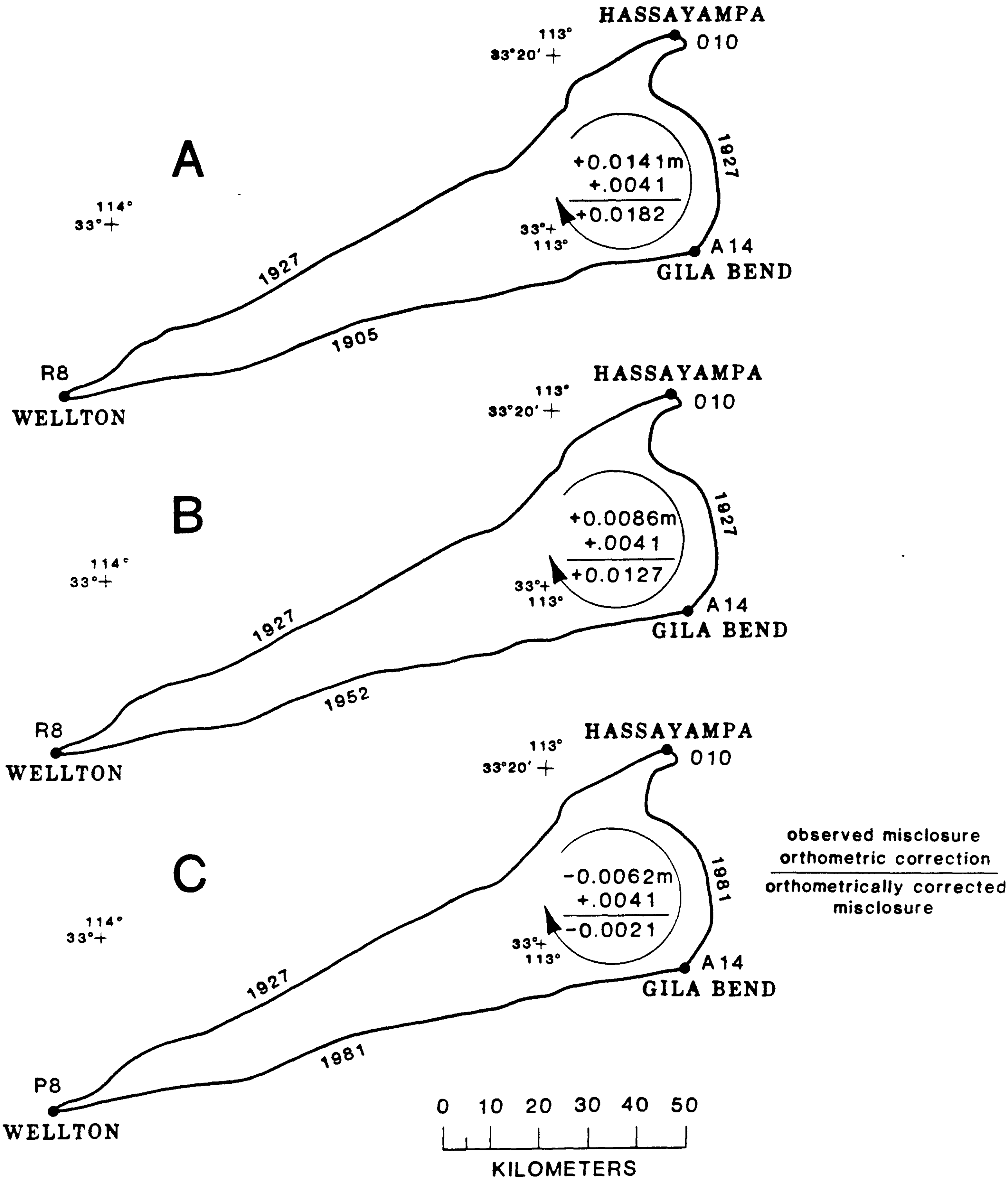


Figure 4. Misclosures around the southwestern Arizona circuit Wellton-Hassayampa-Gila Bend-Wellton based on various combinations of first-order levelings. A 1905/1927. B 1927/1952. C 1927/1981. The conventions adopted here are used throughout this report: (1) all summations are clockwise; (2) the upper figure is the summation of the observed elevation differences around the circuit; (3) the figure on the second line is the summation of the orthometric corrections around this same circuit; and (4) the sum of the two preceding figures is shown on the bottom line and forms the orthometrically corrected misclosure around the indicated circuit. Orthometric corrections based on observed gravity.

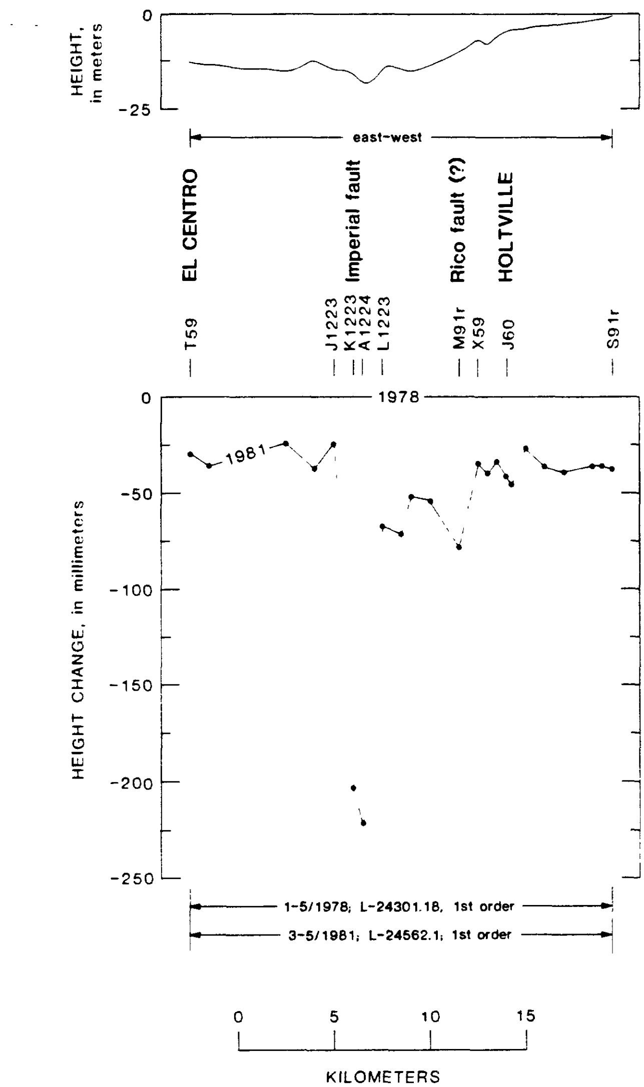


Figure 5. Profiles showing terrain and height changes during the period 1978-1981 across the Imperial fault between El Centro and about 10 km east of Holtville. Exaggerated terrain profile emphasizes tectonic control of near-fault topography.

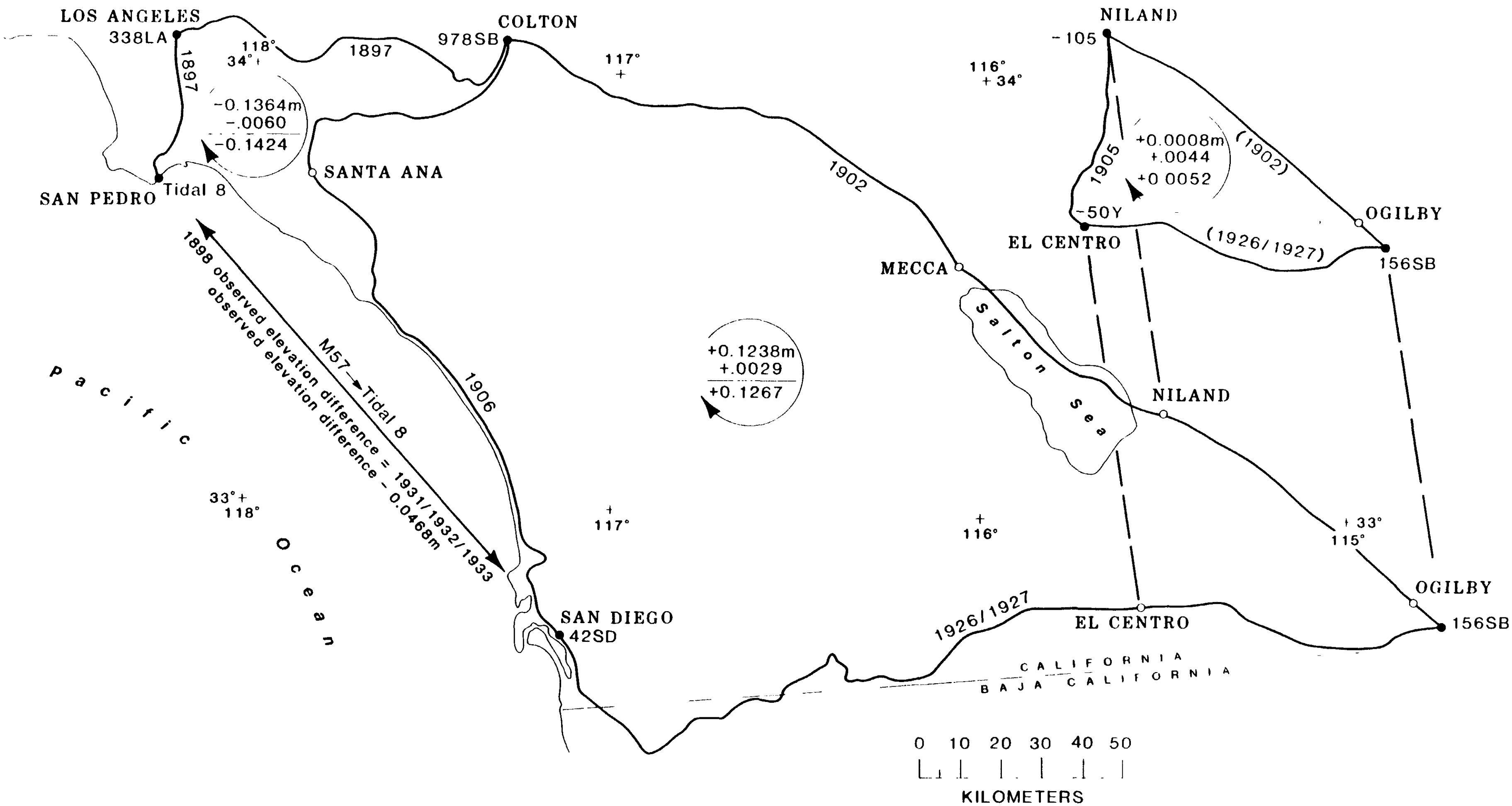


Figure 6. Misclosures around the 1897/1906 circuit San Diego-San Pedro-Los Angeles-Colton-Santa Ana-San Diego, the 1902/1906/1926/1927 circuit San Diego-Santa Ana-Colton-Mecca-Ogilby-El Centro-San Diego, and the 1902/1905/1926/1927 circuit El Centro-Old Beach (Niland)-Ogilby-El Centro (inset). The 1897/1906 misclosure is derived from 1931/1932/1933 leveling between San Diego and San Pedro, corrected to an 1897-equivalent based on the known rate of uplift of the San Pedro tide station of 1.56 mm/yr with respect to San Diego (see text for details). 1897, 1902 and 1905 surveys run to third-order standards; all other levelings are first-order.

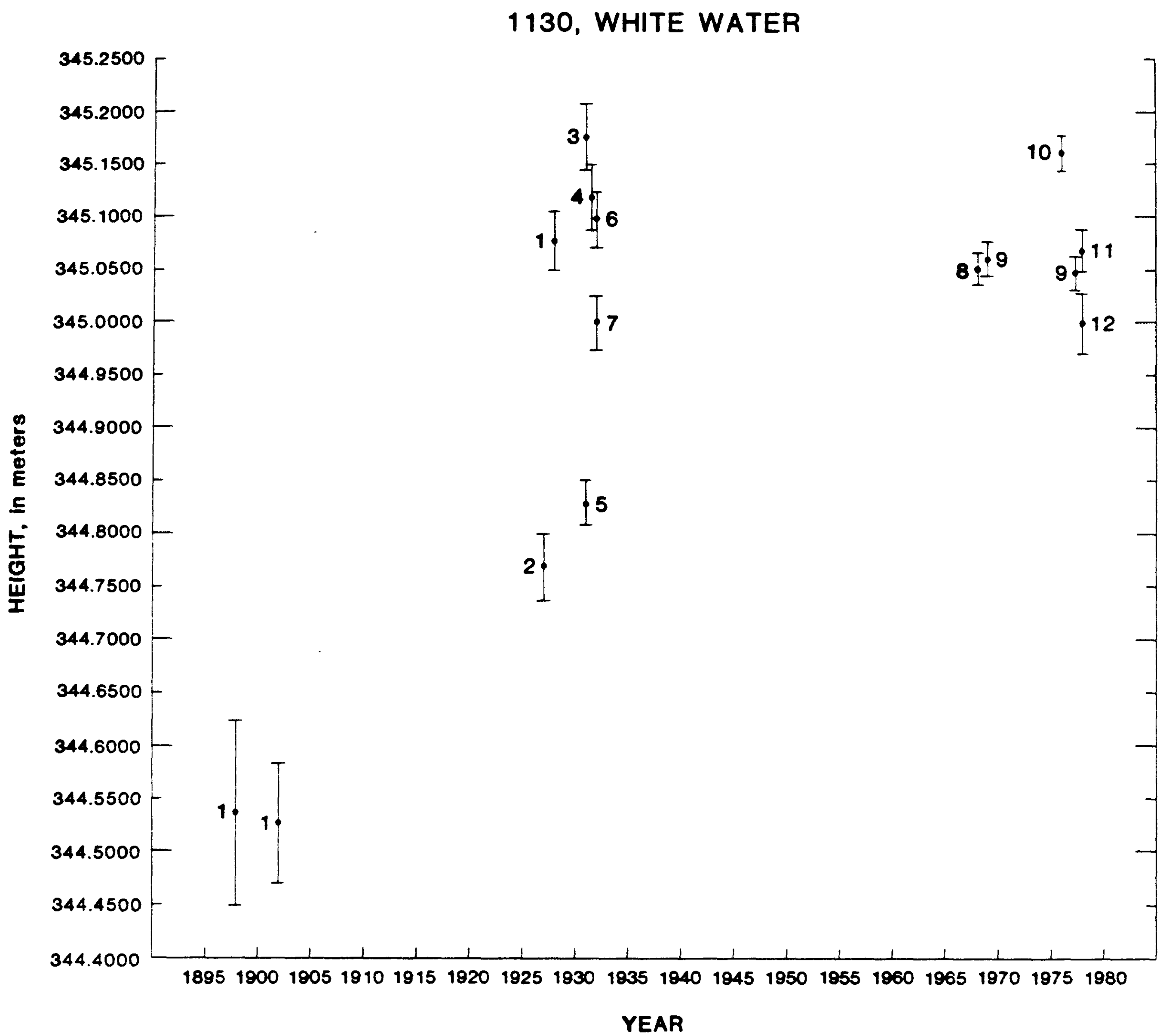


Figure 7. Changes in orthometric height at bench mark 1130, White Water, with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via San Pedro, Los Angeles, and Colton
2 via Jacumba, El Centro, Niland, and Mecca
3 via San Pedro, Los Angeles, and Riverside
4 via San Pedro, Santa Ana, Riverside, San Jacinto, and Banning
5 via Bill Williams River, Freda Junction, Cottonwood Pass, and Indio
6 via Oceanside, Santa Ana, Riverside, San Jacinto, and Banning
7 via Oceanside, Aguanga, San Jacinto, and Banning
8 via San Ysidro, Campo, Julian, Salton City, and Mecca
9 via Miramar, Julian, Salton City, and Mecca
10 via Bill Williams River, Freda Junction, Cottonwood Pass, and Mecca
11 via Miramar, Julian, El Centro, Niland, and Mecca
12 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca.

Reconstructions outlined in detail in Appendix, Tables C1-C15. Error bars show one standard deviation value for estimated random error only.

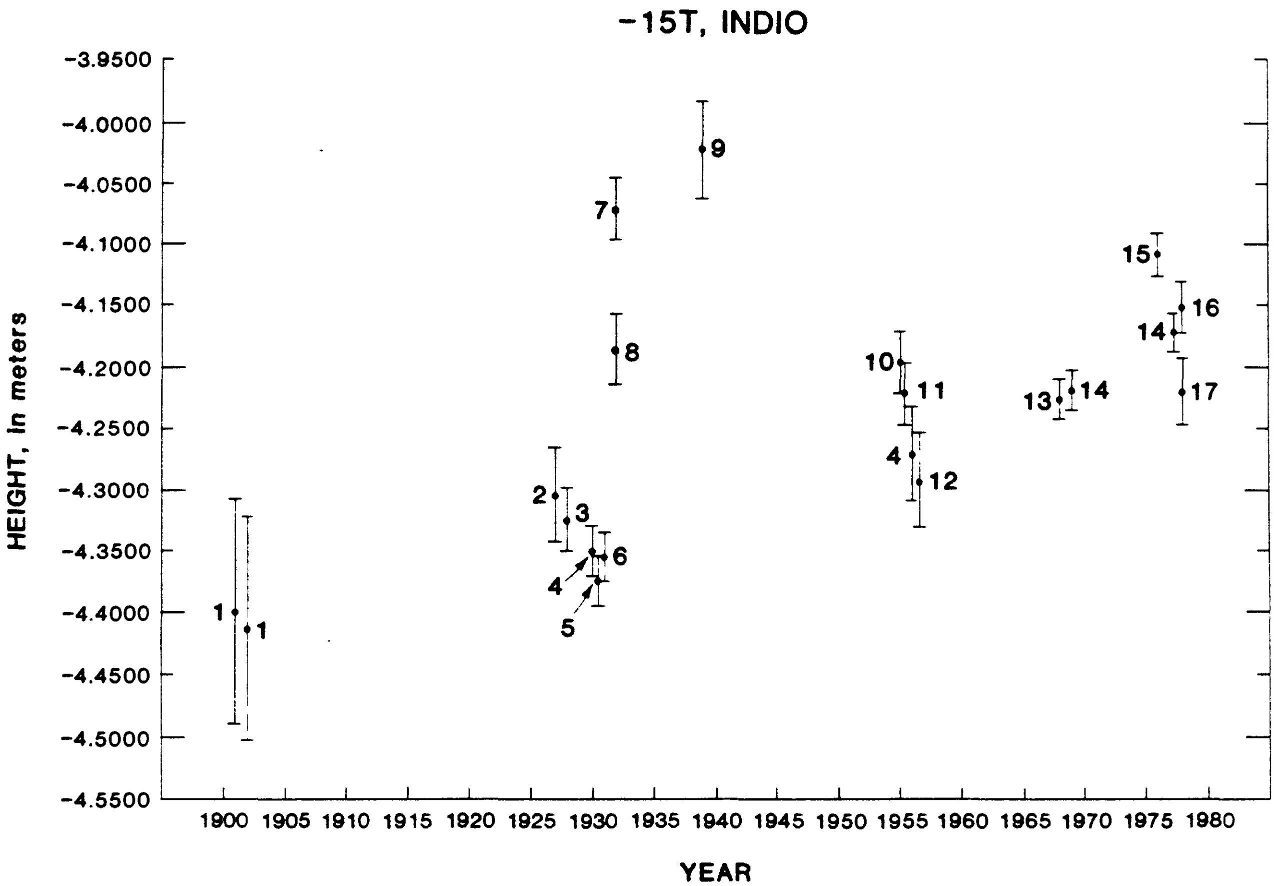


Figure 8. Changes in orthometric height at bench mark -15T, Indio, with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via San Pedro, Los Angeles, and Colton
2 via La Mesa, Santa Ysabel, and Aguanga
3 via Jacumba, El Centro, Niland, and Mecca
4 via Hassayampa, Salome, Blythe, Ogilby, El Centro, Niland, and Mecca
5 via Hassayampa, Salome, Blythe, Ogilby, Niland, and Mecca
6 via Bill Williams River, Freda Junction, Cottonwood Pass, and Fargo Junction
7 via San Pedro, Los Angeles, and Riverside
8 via Oceanside, Aguanga, San Jacinto, Banning, and White Water
9 via Santa Ysabel, Julian, Truckhaven, and Mecca
10 via La Mesa, Julian, Truckhaven, and Mecca
11 via Miramar, Julian, Truckhaven, and Mecca
12 via Miramar, Santa Ysabel, and Aguanga
13 via San Ysidro, Campo, Julian, Salton City, and Mecca
14 via Miramar, Santa Ysabel, Julian, Salton City, and Mecca
15 via Bill Williams River, Freda Junction, Cottonwood Pass, and Mecca
16 via Miramar, Julian, Ocotillo, El Centro, Niland, and Mecca
17 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca.

Reconstructions outlined in detail in Appendix, Tables D1-D19. Error bars show one standard deviation value for estimated random error only.

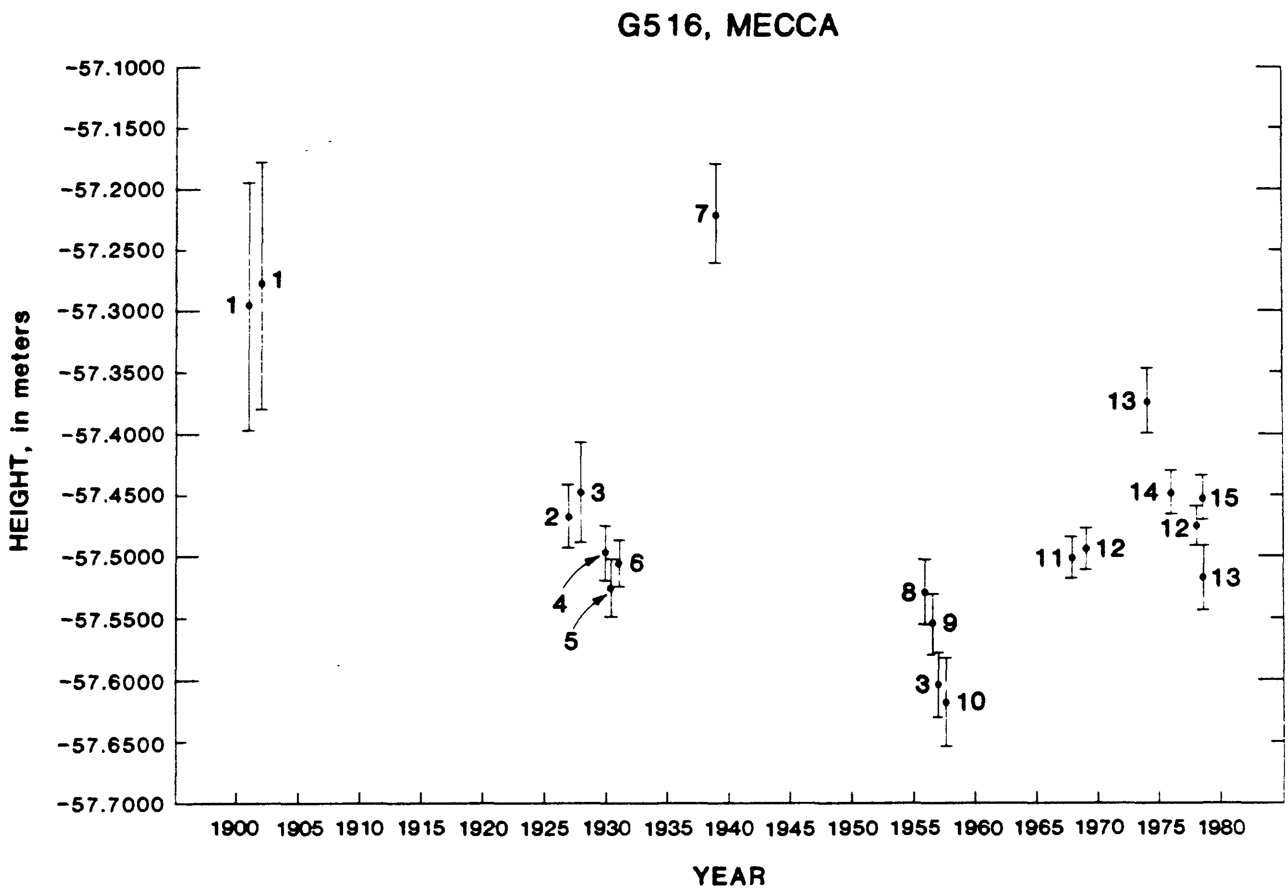


Figure 9. Changes in orthometric height at bench mark G516 (or its reset equivalent), Mecca, with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via San Pedro, Los Angeles, and Colton
2 via Jacumba, El Centro, and Niland
3 via La Mesa, Santa Ysabel, Aguanga, and Indio
4 via Hassayampa, Salome, Blythe, Ogilby, El Centro, and Niland
5 via Hassayampa, Salome, Blythe, Ogilby, and Niland
6 via Bill Williams River, Freda Junction, and Cottonwood Pass
7 via Santa Ysabel, Julian, and Truckhaven
8 via La Mesa, Santa Ysabel, Julian, and Truckhaven
9 via Miramar, Santa Ysabel, Julian, and Truckhaven
10 via Miramar, Santa Ysabel, Aguanga, and Indio
11 via San Ysidro, Campo, Julian, and Salton City
12 via Miramar, Santa Ysabel, Julian, and Salton City
13 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, and Cottonwood Pass
14 via Bill Williams River, Freda Junction, and Cottonwood Pass
15 via Miramar, Julian, Ocotillo, El Centro, and Niland.

Reconstructions outlined in detail in Appendix, Tables E1-E20 and Table 4. Error bars show one standard deviation value for estimated random error only.

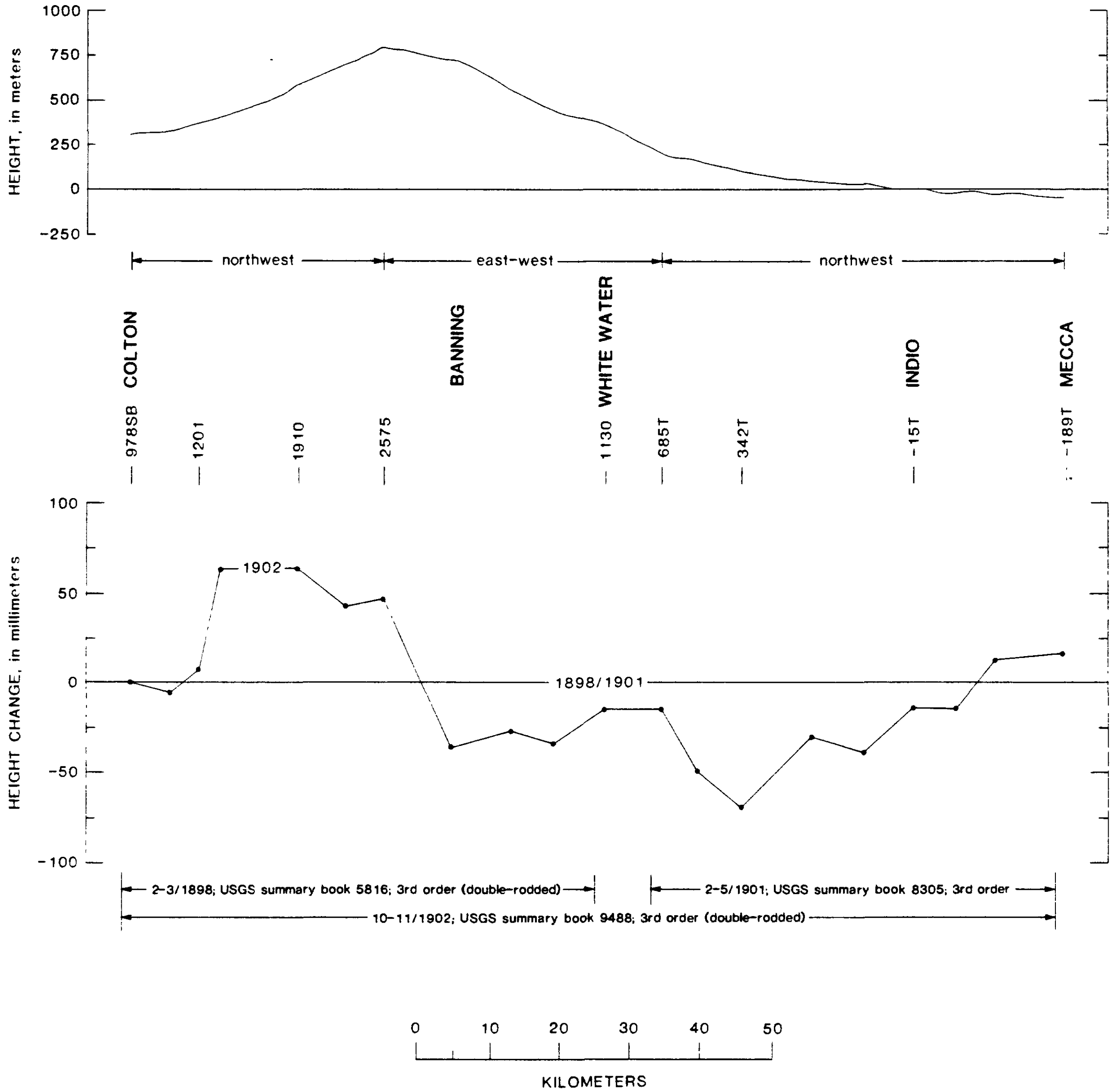


Figure 10. Profiles showing terrain and height changes along the axis of the northern Salton Trough between Colton and Mecca, with respect bench mark 978SB, Colton. Tie between discontinuous 1898 and 1901 levelings southeast of White Water based on an assumption of invariance between bench marks 1130 and 685T during the period 1898-1902 (Castle and others, 1986).

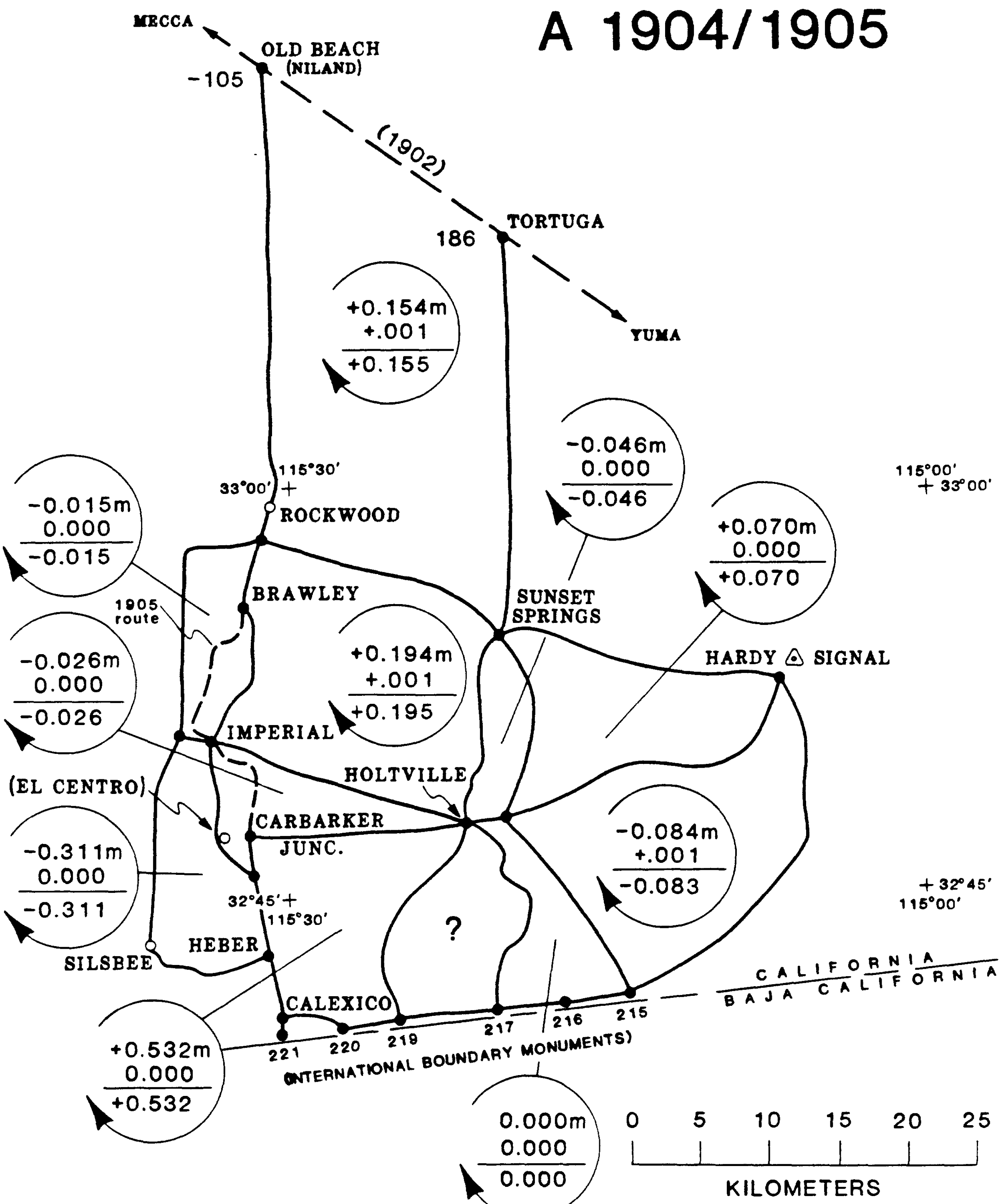
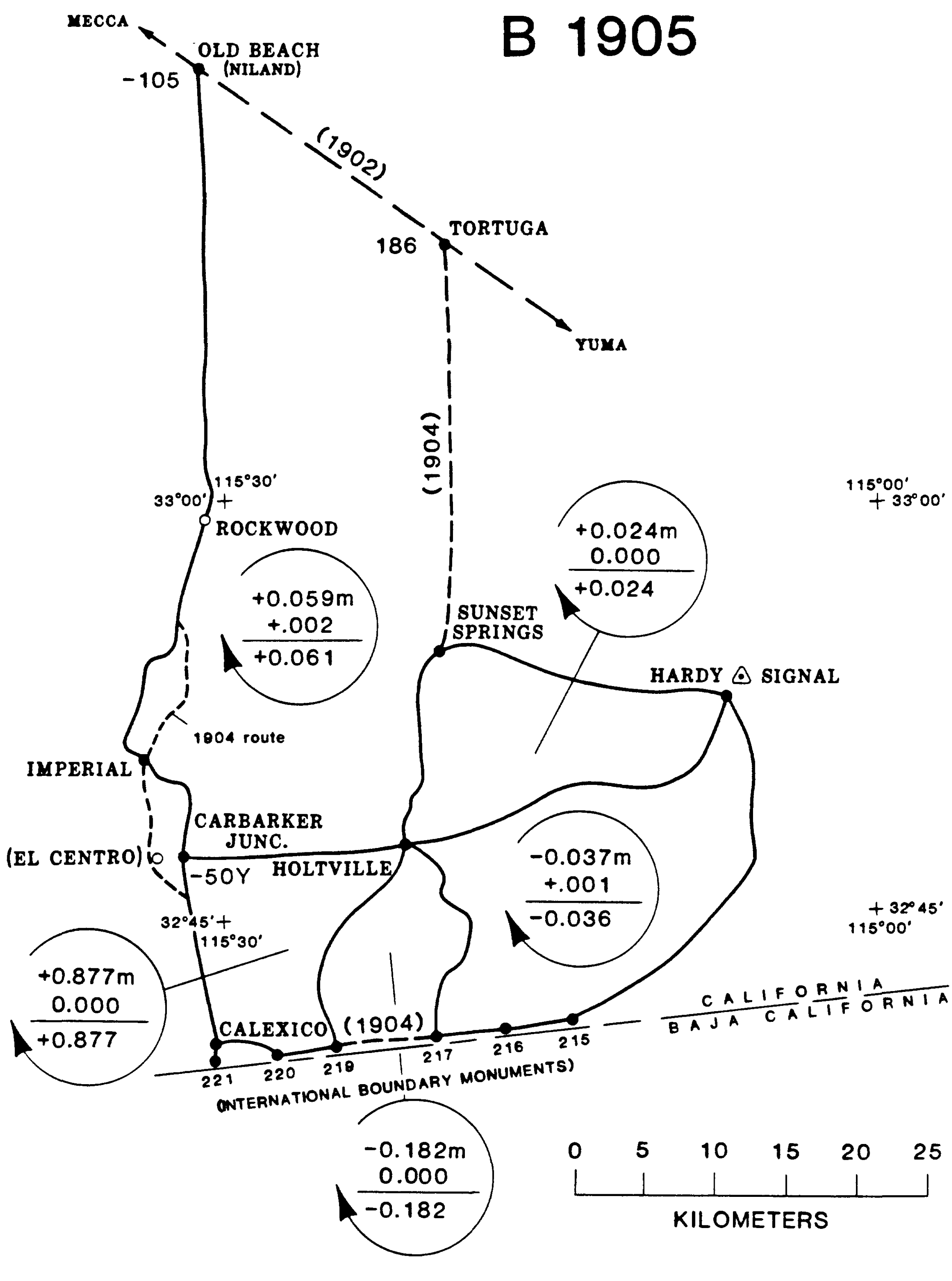


Figure 11. Networks and circuit misclosures based on early 1900's third-order levelings in the Imperial Valley. A composite of 1904/1905 levelings. B primarily 1905 levelings.


B 1905
MECCA
OLD BEACH
(NILAND)
-105
(1902)
TORTUGA
186
YUMA
(1904)
115°30'
33°00'
ROCKWOOD
115°00'
33°00'
+0.024m
0.000
+0.024
+0.059m
+.002
+0.061
SUNSET
SPRINGS
HARDY SIGNAL
1904 route
IMPERIAL
CARBARKER
JUNC.
(EL CENTRO)
-50Y
HOLTVILLE
-0.037m
+.001
-0.036
32°45'
115°30'
32°45'
115°00'
+0.877m
0.000
+0.877
CALIFORNIA
BAJA CALIFORNIA
CALEXICO
(1904)
221
220
219
217
216
215
(INTERNATIONAL BOUNDARY MONUMENTS)
-0.182m
0.000
-0.182
0 5 10 15 20 25
KILOMETERS

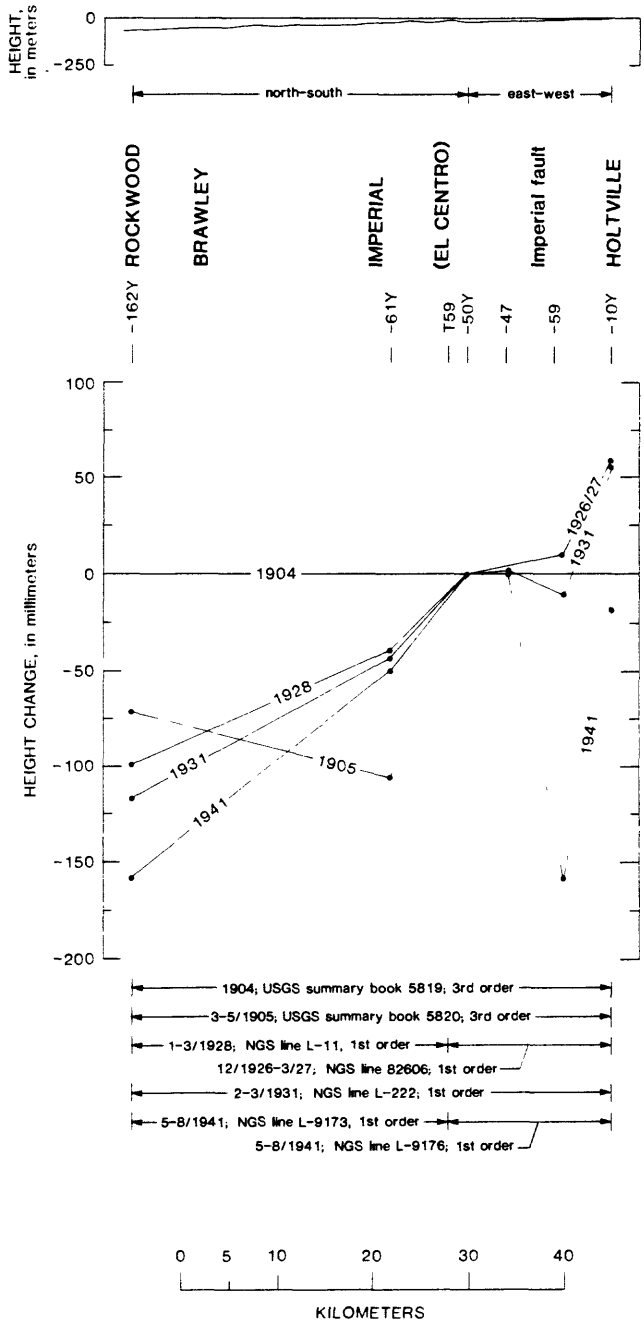


Figure 12. Profiles showing terrain and height changes against a 1904 datum in the Imperial Valley between Rockwood, El Centro, and Holtville, with respect to bench mark -50Y, near El Centro.

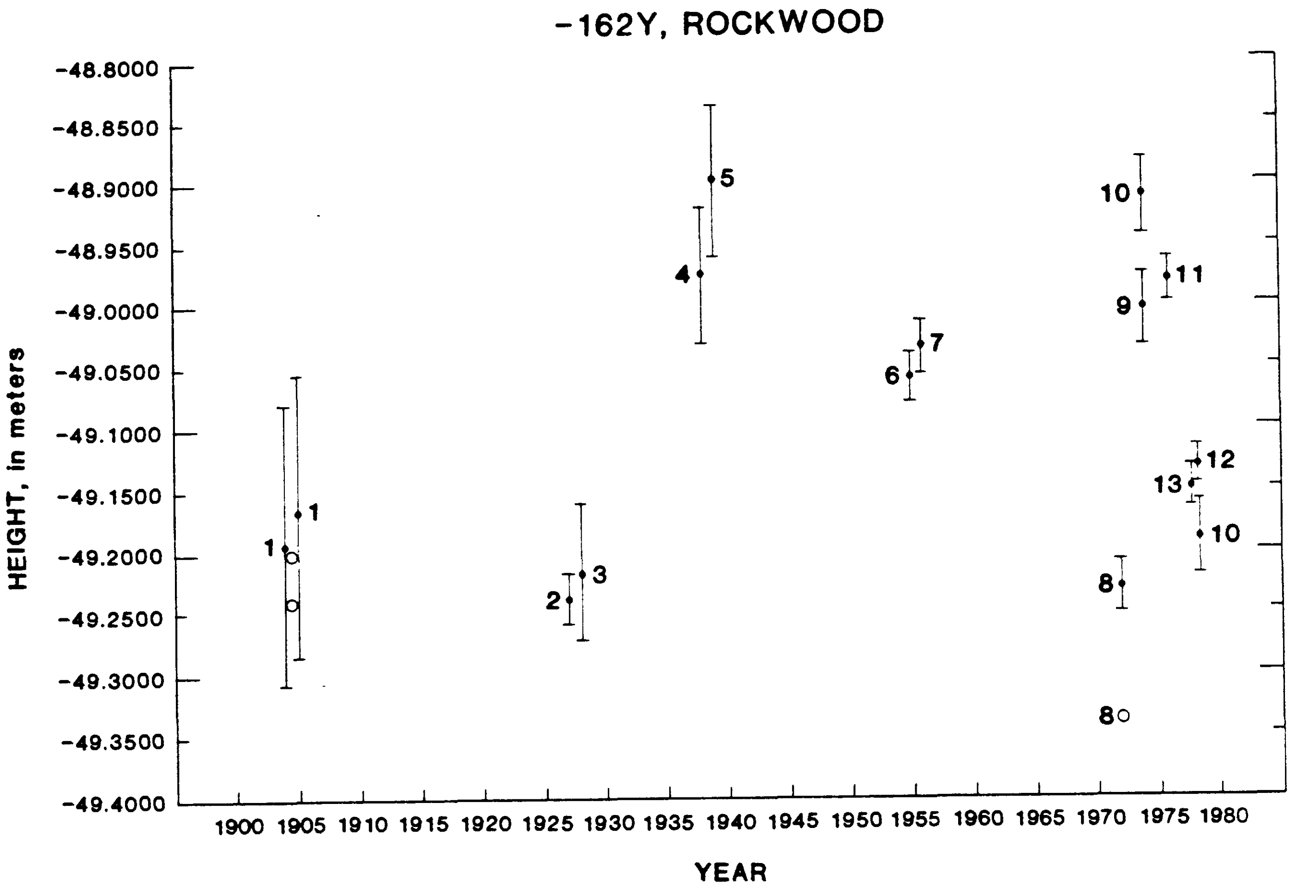


Figure 13. Changes in orthometric height at bench mark -162Y, Rockwood (about 7 km north of Brawley), with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via San Pedro, Los Angeles, Colton, Mecca, and Old Beach, (Niland)
2 via Jacumba, and El Centro
3 via La Mesa, Santa Ysabel, Aguanga, Indio, and Niland
4 via San Ysidro, Campo, Pine Valley, Jacumba, and El Centro
5 via Santa Ysabel, Julian, and Truckhaven
6 via Miramar, Ramona, Julian, and Truckhaven
7 via La Mesa, Ramona, Julian, and Truckhaven
8 via Hassayampa, Salome, Blythe, Palo Verde, Ogilby, and El Centro
9 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Mecca, and Salton City
10 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Mecca, and Niland
11 via Bill Williams River, Freda Junction, Cottonwood Pass, Mecca, and Niland
12 via Miramar, Julian, Ocotillo. and El Centro
13 via Miramar, Julian, Salton City, Mecca, and Niland.

Reconstructions outlined in detail in Appendix, Tables H1-H15. Open circle 1904 heights based on alternative interpretations of field elevation differences between Rockwood and Old Beach given in USGS summary book 5819; see Appendix Table H1, note 3 for details. Open circle 1972 height based on an assumption of invariance at Palo Verde between 1933 and 1972 (see text for details). Error bars show one standard deviation value for estimated random error only.

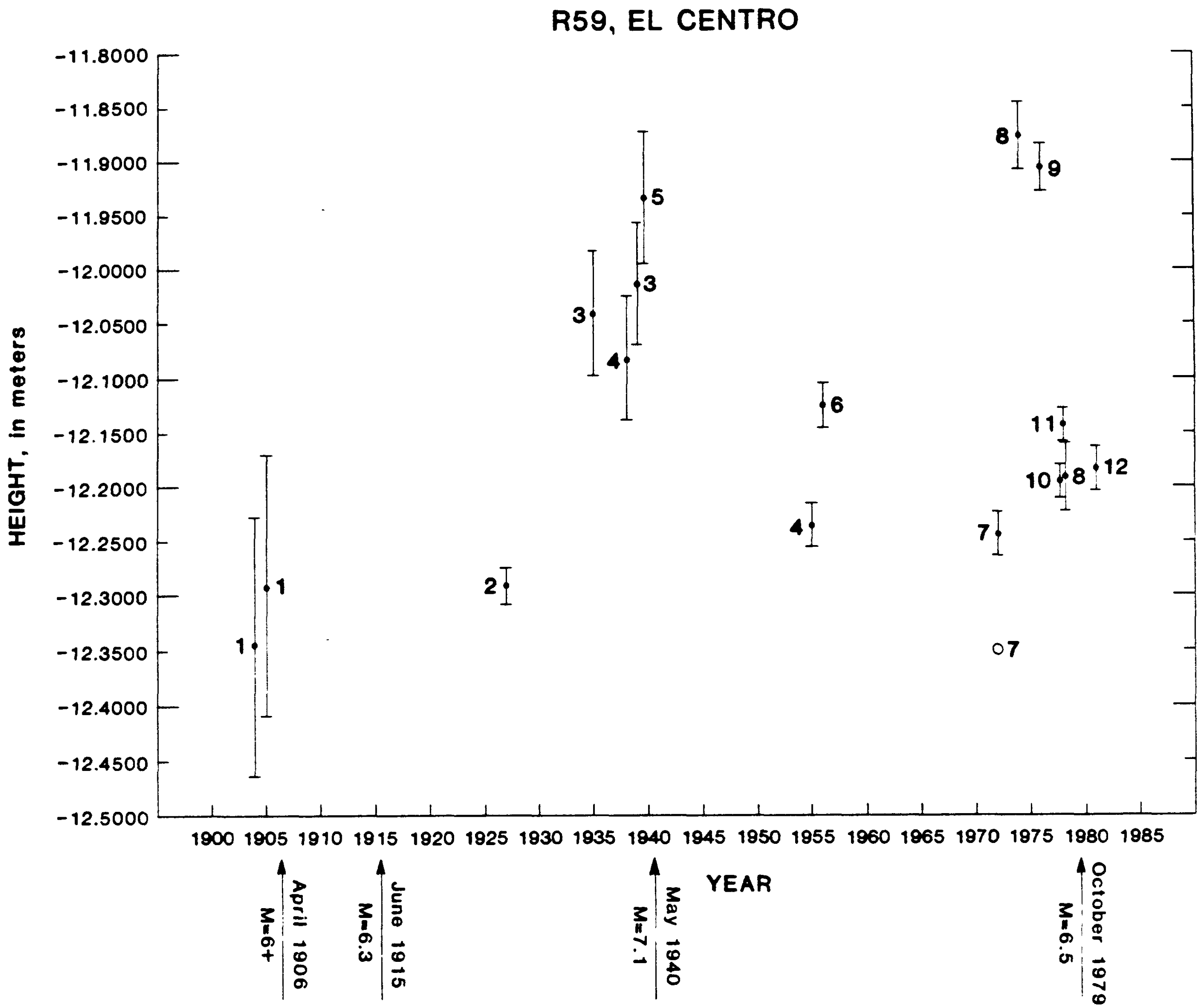


Figure 14. Changes in orthometric height at bench mark R59, El Centro, with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via San Pedro, Los Angeles, Colton, Mecca, and Old Beach (Niland)
2 via San Ysidro, Campo, and Ocotillo
3 via San Ysidro, Campo, Pine Valley, and Jacumba
4 via Santa Ysabel, Julian, Truckhaven, and Rockwood
5 via La Mesa, Julian, Truckhaven, and Rockwood
6 via Hassayampa, Salome, Blythe, Palo Verde, and Ogilby
7 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, Mecca, and Niland
8 via Bill Williams River, Freda Junction, Cottonwood Pass, Mecca, and Niland
9 via Miramar, Julian, and Ocotillo
10 via Miramar, Julian, Salton City, Mecca, and Niland
11 via Hassayampa, and Yuma.

Reconstructions outlined in detail in Appendix, Tables I1-I14. Open circle 1972 based on assumption of invariance at Palo Verde between 1933 and 1972 (see text for details). Error bars show one standard deviation value for estimated random error only.

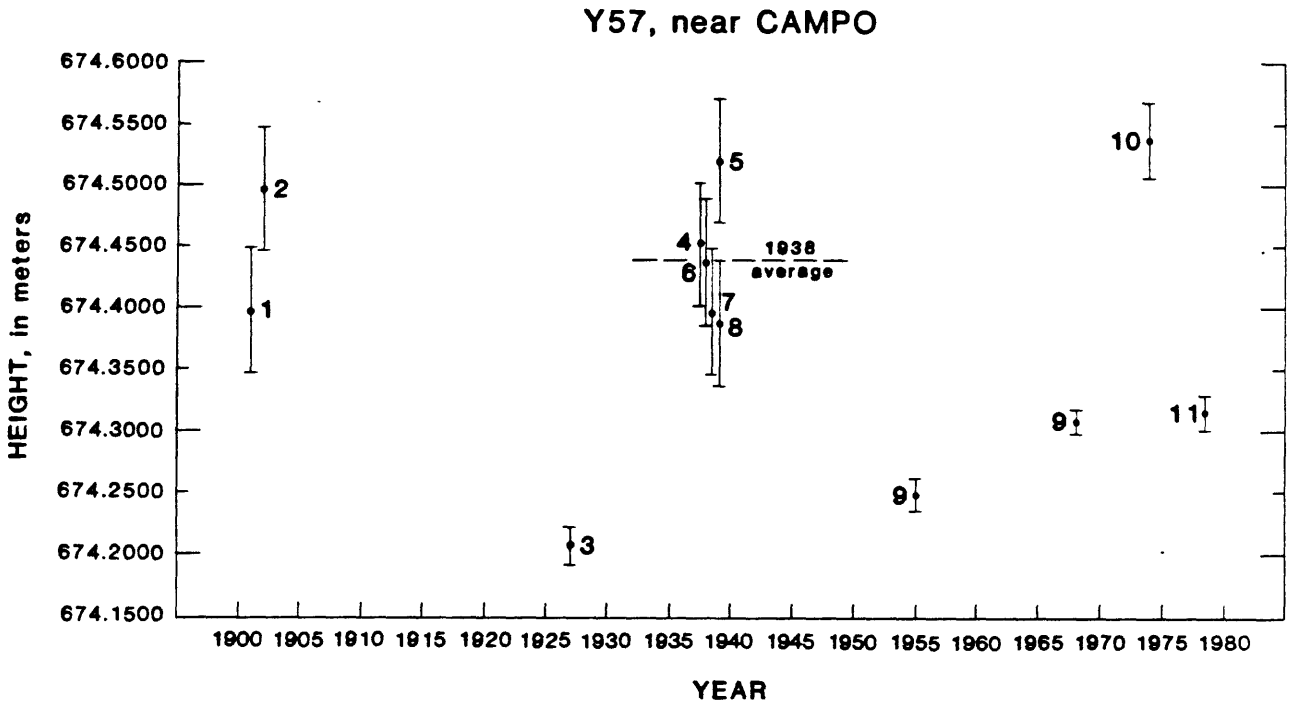


Figure 15. Changes in orthometric height at bench mark Y57, near Campo, with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via Otay, Jamul, and Potrero (tie through bm 2323)
2 via Otay, Jamul, and Potrero (tie through bm 2543)
3 via San Ysidro and northern Baja California
4 via La Mesa, Jamul, Dulzura, and Barrett Junction
5 via National City, La Presa, Jamul, Dulzura, and Barrett Junction
6 via Chula Vista, Jamul, Dulzura, and Barrett Junction
7 via Chula Vista, Otay Dam, Kuebler Ranch, Dulzura, and Barrett Junction
8 via San Ysidro, Kuebler Ranch, Dulzura, and Barrett Junction
9 via San Ysidro, Dulzura, and Barrett Junction
10 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Mecca, Niland, El Centro, and Ocotillo
11 via Miramar, Julian, and Pine Valley.

Reconstructions outlined in detail in Appendix, Tables K1-K13. Routes defining 1938/1939 heights (4-8) are shown in fig. 23. Error bars show one standard deviation value for estimated random error only.

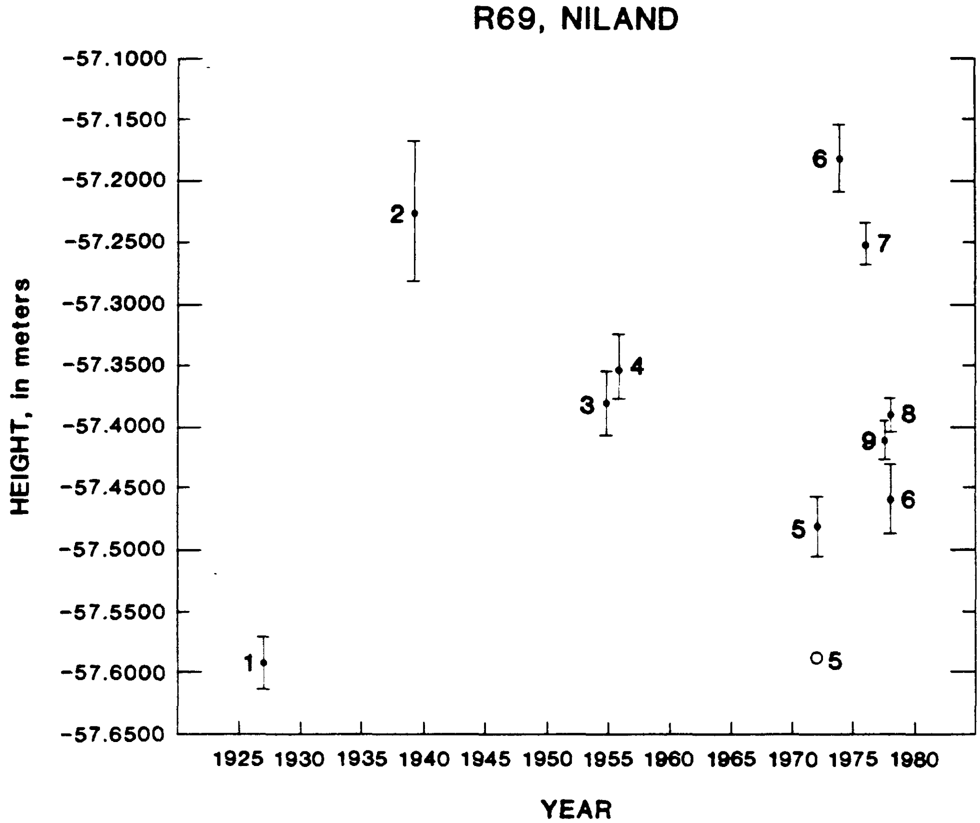


Figure 16. Changes in orthometric height at bench mark R69, Niland, with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via Jacumba and El Centro
2 via Santa Ysabel, Truckhaven, and Rockwood
3 via Miramar, Ramona, Julian, Truckhaven, and Rockwood
4 via La Mesa, Ramona, Julian, Truckhaven, and Rockwood
5 via Hassayampa, Salome, Blythe, Palo Verde, Ogilby, and El Centro
6 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca
7 via Bill Williams River, Freda Junction, Cottonwood Pass, and Mecca
8 via Miramar, Julian, Ocotillo, and El Centro
9 via Miramar, Julian, Salton City, and Mecca.

Reconstructions outlined in detail in Appendix, Tables G1-G10. Open circle 1972 height based on an assumption of invariance at Palo Verde between 1933 and 1972 (see text for details). Error bars show one standard deviation value for estimated random error only.

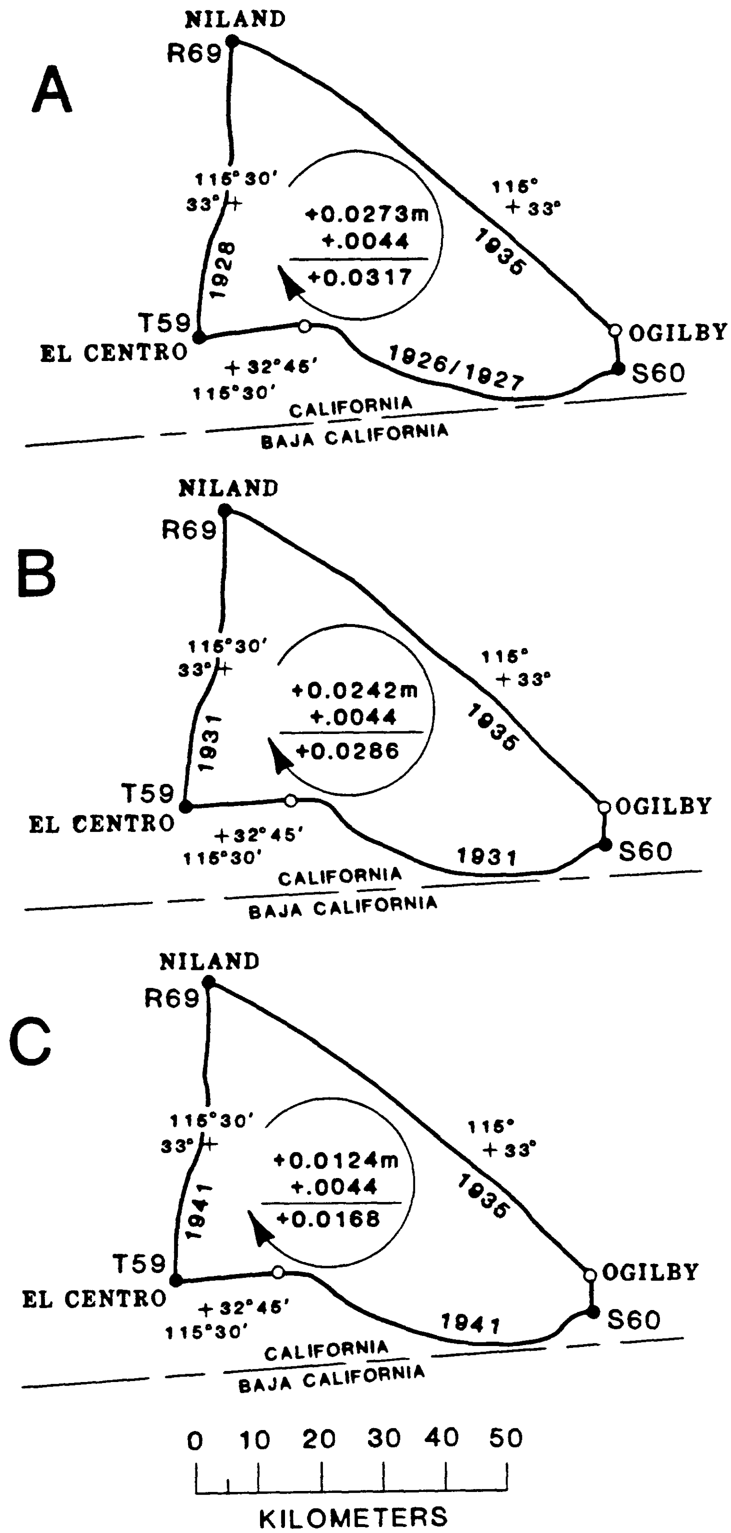


Figure 17. Misclosures around the Imperial Valley circuit El Centro-Niland-Ogilby-El Centro based on various combinations of levelings. A 1926/1927/1928/1935. B 1931/1935. C 1935/1941. 1935 survey run to second-order standards; all other levelings are first-order.

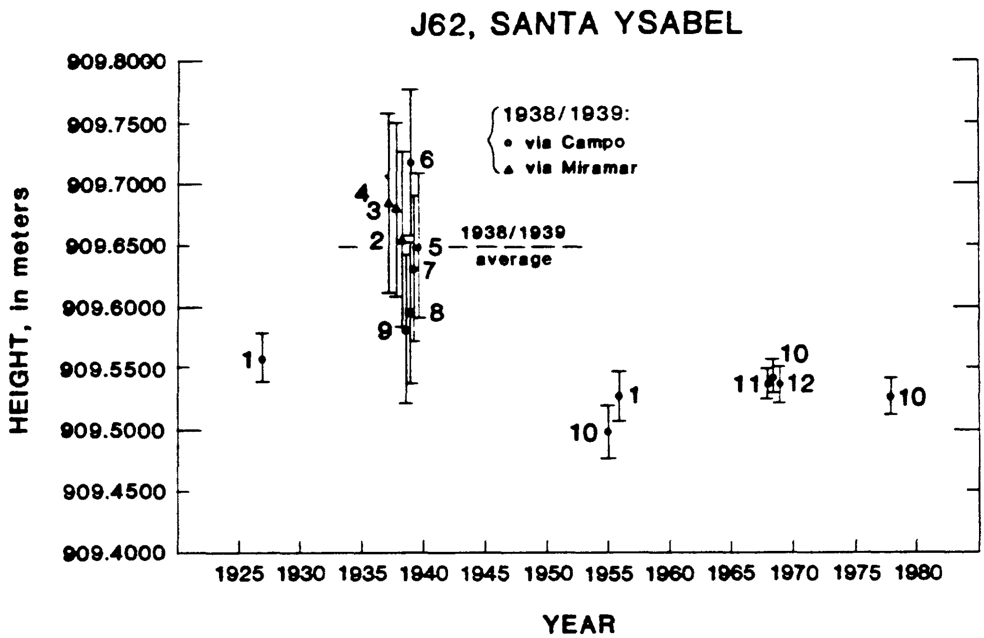


Figure 18. Changes in orthometric height at bench mark J62, Santa Ysabel, with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via La Mesa and Ramona
2 via Grantville, Poway, Ramona, Barona Valley, Tule Springs, and Julian
3 via Grantville, Santee, Poway, Ramona, Barona Valley, Tule Springs, and Julian
4 via Grantville, Santee, Lakeside, Barona Valley, Tule Springs, and Julian
5 via La Mesa, Jamul, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian
6 via National City, La Presa, Jamul, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian
7 via Chula Vista, Jamul, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian
8 via Chula Vista, Otay Dam, Kuebler Ranch, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian
9 via San Ysidro, Kuebler Ranch, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian
10 via Miramar and Ramona
11 via San Ysidro, Campo, and Julian
12 via Oceanside and Pala.

Reconstructions outlined in detail in Appendix, Tables J1-J15. Routes defining 1938/1939 heights (2-9) shown in fig. 23. Error bars show one standard deviation value for estimated random error only.

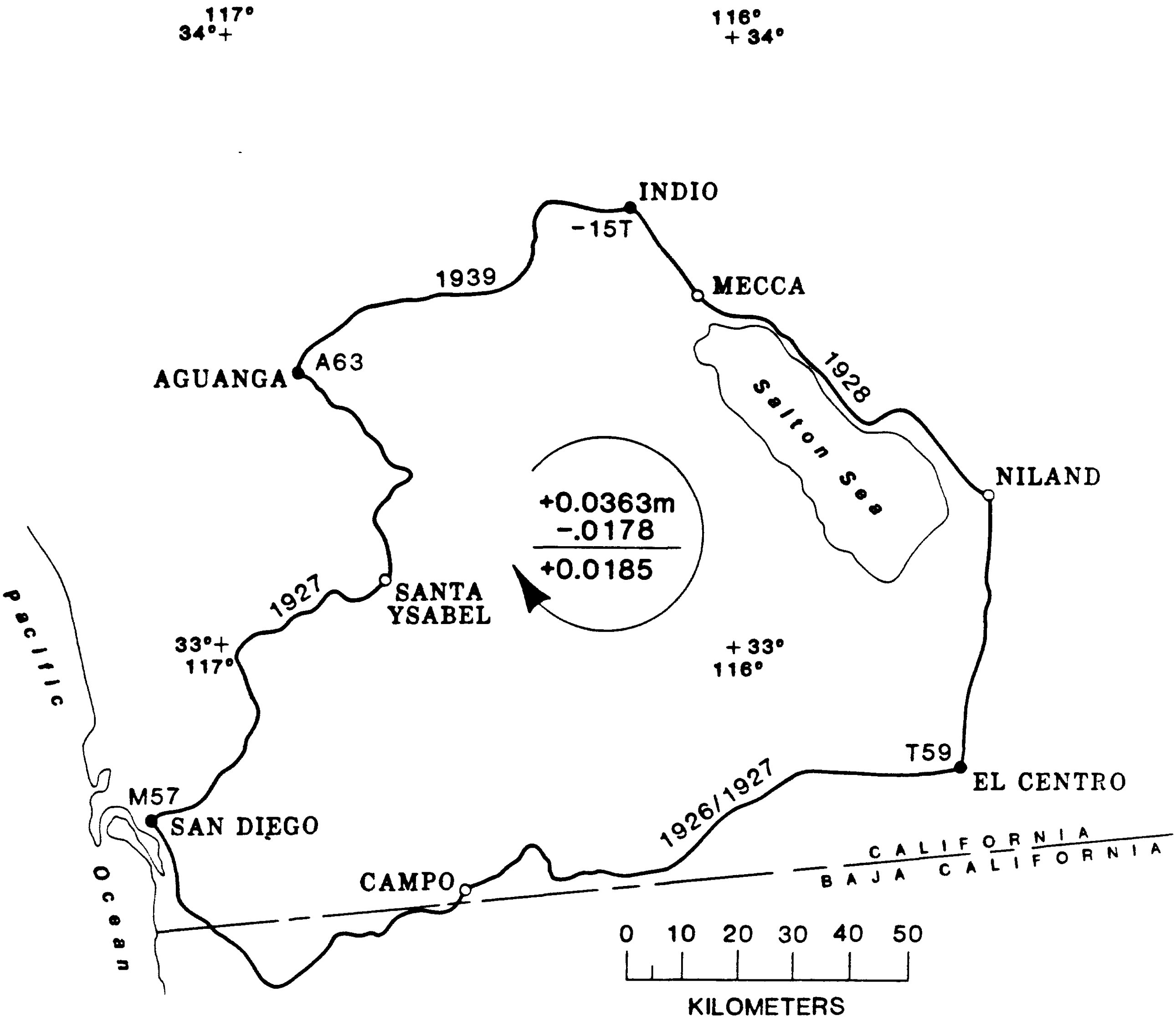


Figure 19. Misclosure around the 1926/1927/1928/1939 circuit San Diego-Santa Ysabel-Aguanga-Indio-El Centro-San Diego. 1939 survey run to second-order standards; all other levelings are first-order.

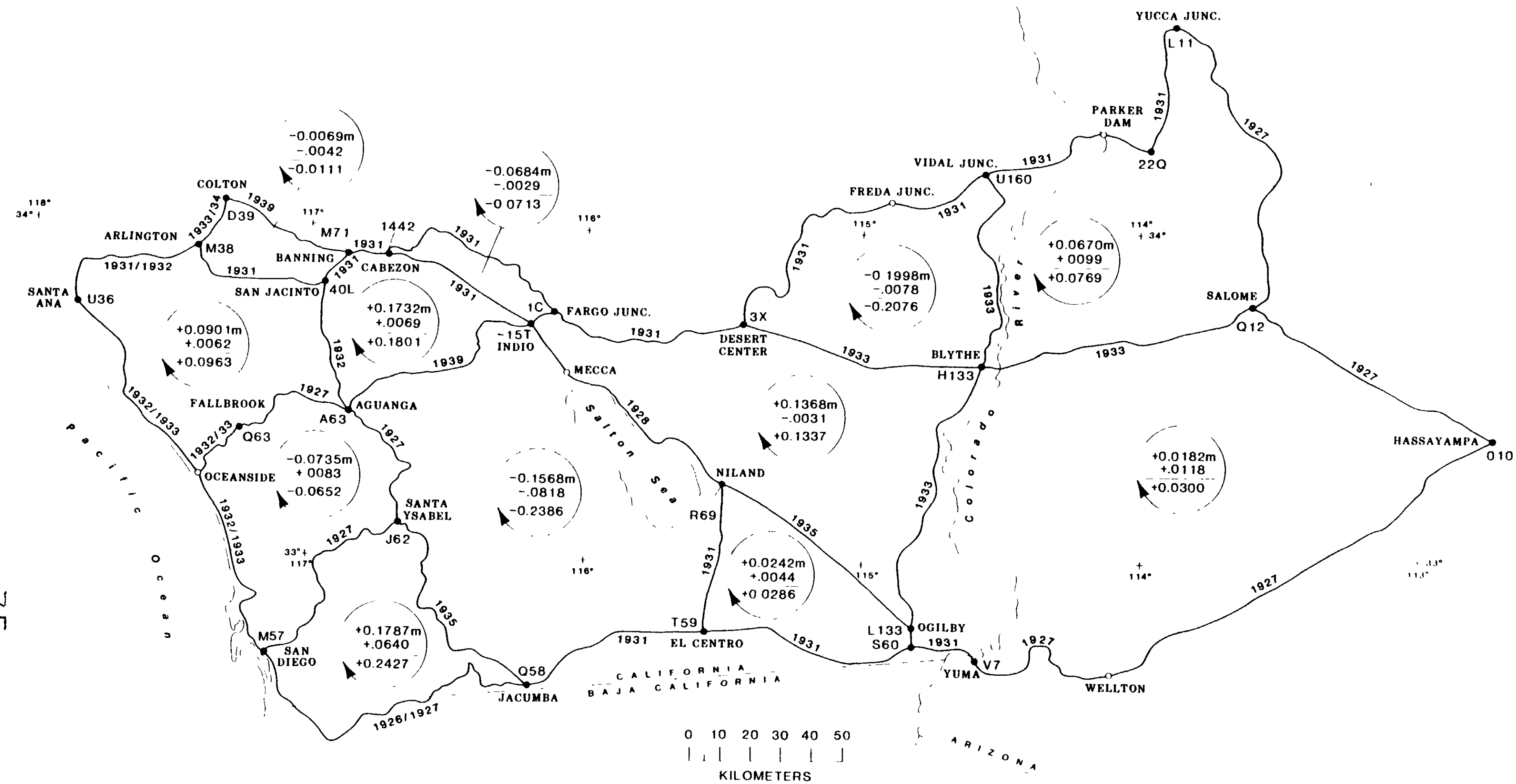


Figure 20. Network and circuit misclosures based on late 1920's and early 1930's levelings in southeastern California and southwestern Arizona.

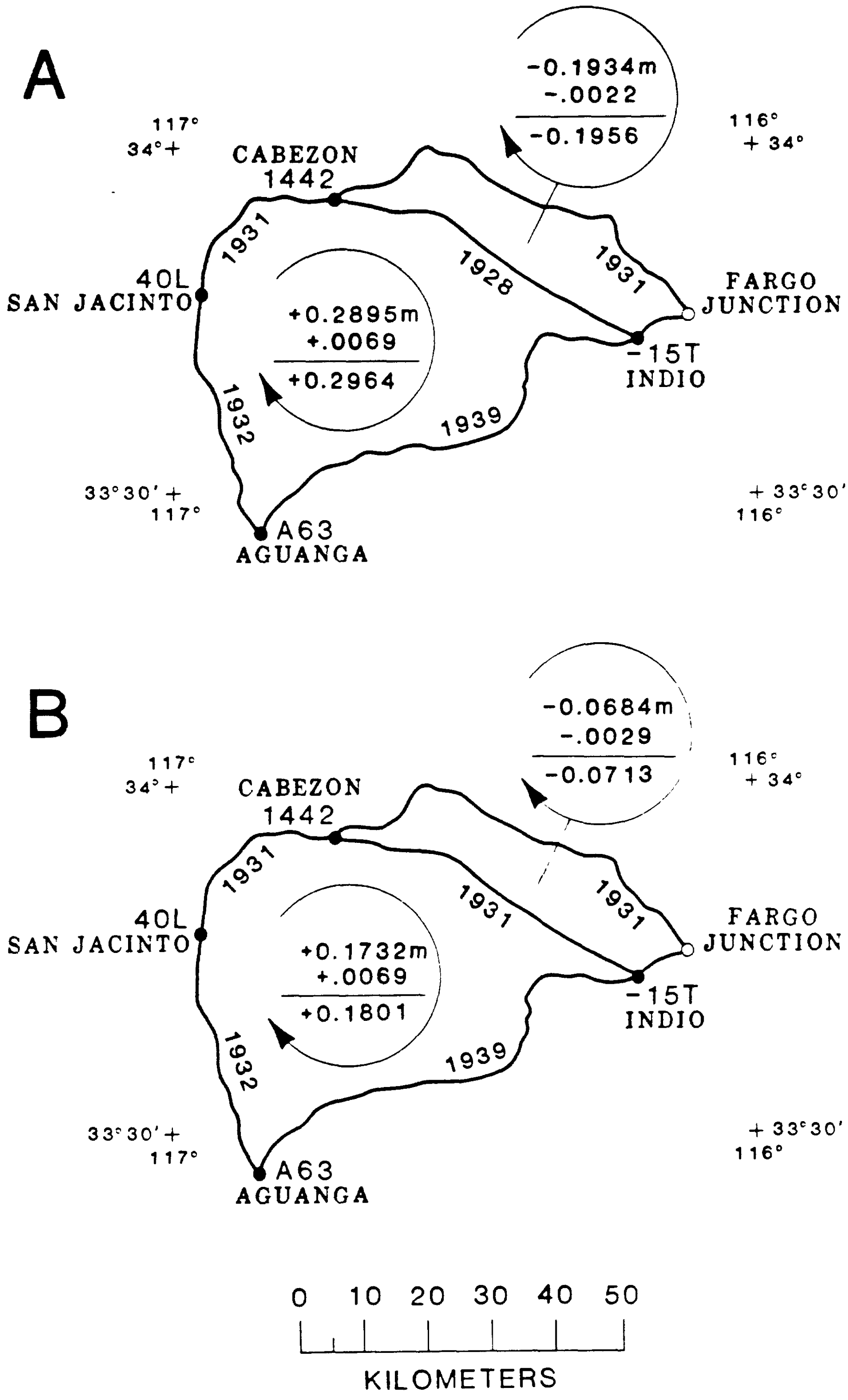


Figure 21. Misclosures around the circuits Cabezon-Fargo Junction-Indio-Cabezon and Aguanga-San Jacinto-Cabezon-Indio-Aguanga based on various combinations of levelings. A 1928/1931 and 1928/1931/1932/1939, respectively. B 1931 and 1931/1932/1939, respectively. 1932 and 1939 surveys run to second-order standards; all other levelings are first-order.

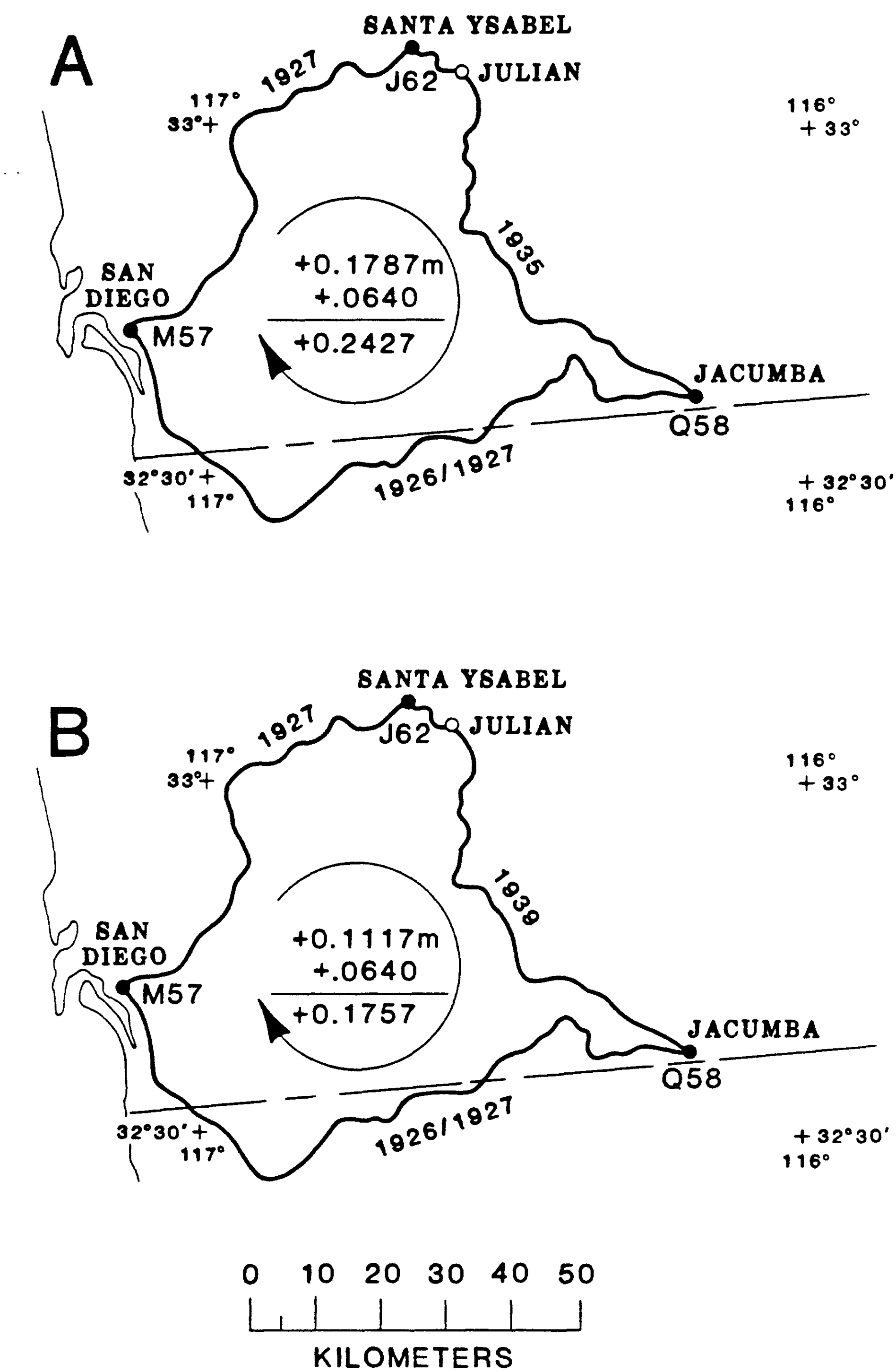


Figure 22. Misclosures around the circuit San Diego-Santa Ysabel-Jacumba-San Diego based on various combinations of levelings. A 1926/1927/1935. B 1926/1927/1939. 1935 and 1939 surveys run to second-order standards; other levelings are first order.

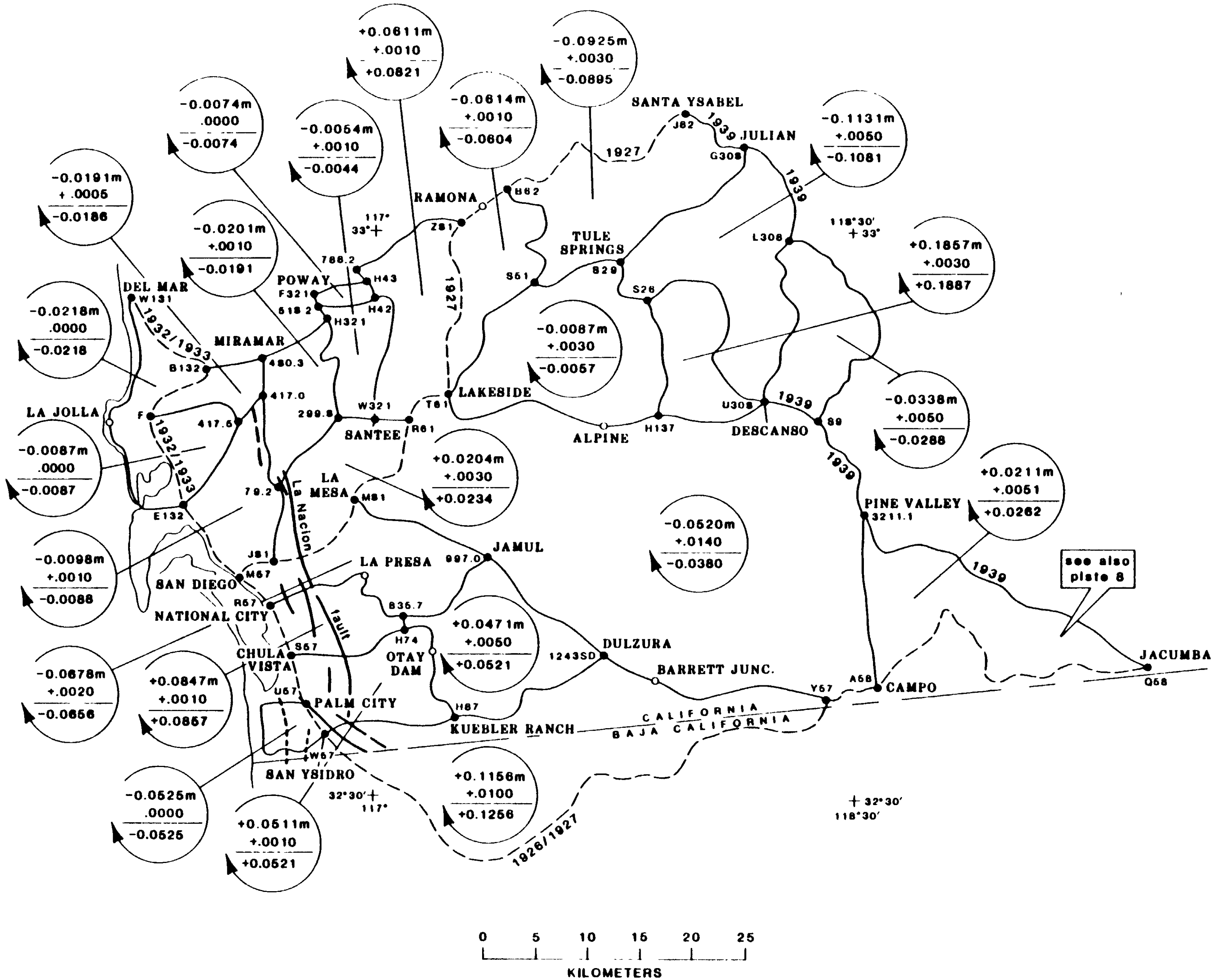


Figure 23. Network and circuit misclosures based on 1938/1939 second- and third-order levelings in the southern Peninsular Ranges. Misclosures of 1938/1939 levelings are developed against first-order surveys (dashed lines) based on 1926/1927 leveling between San Diego and Jacumba, 1927 leveling between San Diego and Santa Ysabel, and 1932/1933 leveling between San Diego and Del Mar. Levelings completed in 1938, unless otherwise designated.

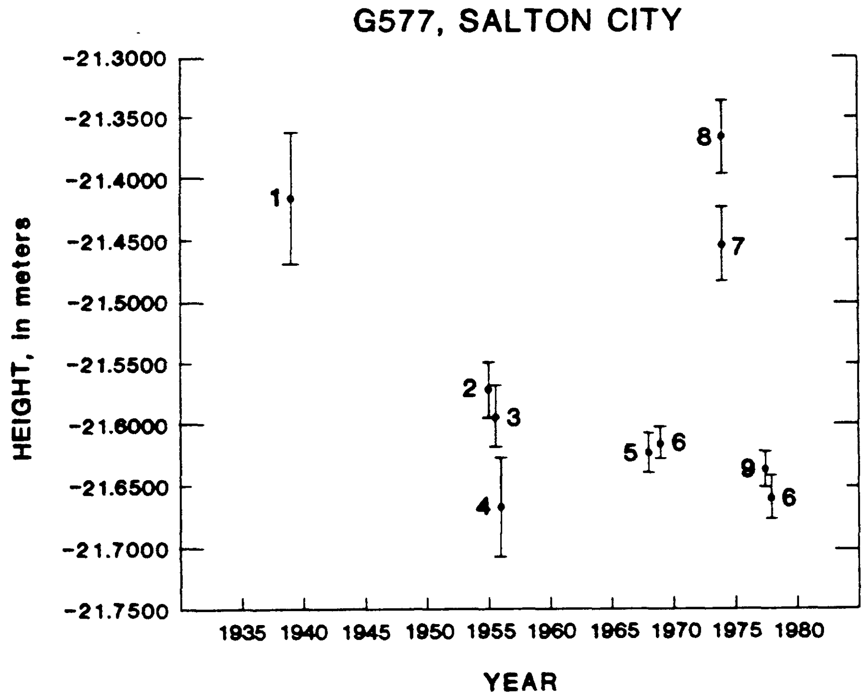


Figure 24. Changes in orthometric height at bench mark G577, Salton City, with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via Santa Ysabel, Julian, and Truckhaven
2 via La Mesa, Ramona, Julian, and Truckhaven
3 via Miramar, Ramona, Julian, and Truckhaven
4 via Miramar, Santa Ysabel, Aguanga, Indio, and Mecca
5 via Campo, Julian, and Borrego
6 via Miramar, Julian, and Borrego
7 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca
8 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, Mecca, Niland, Rockwood, and Truckhaven
9 via Miramar, Julian, El Centro, Niland, and Mecca.

Reconstructions outlined in detail in Appendix, Tables F1-F10. Error bars show one standard deviation value for estimated random error only.

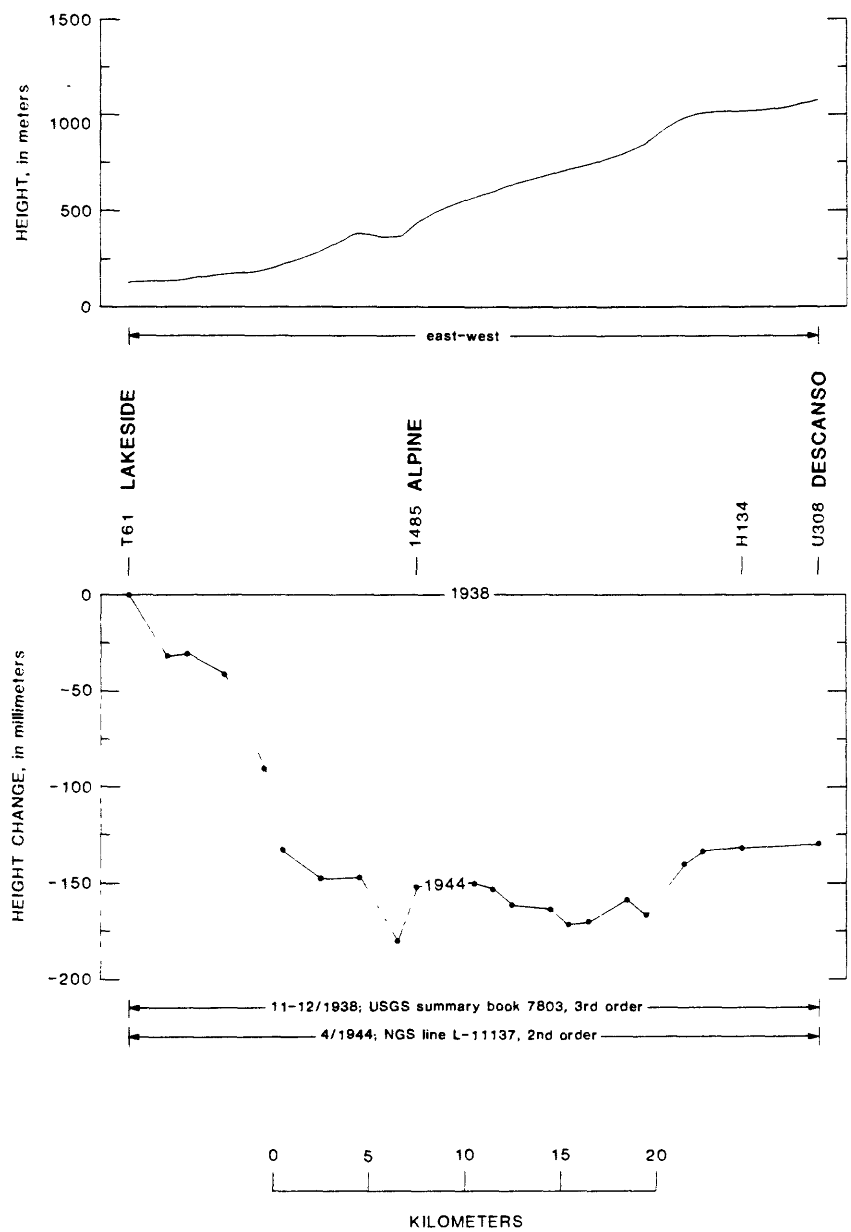


Figure 25. Profiles showing terrain and height changes during the period 1938-1944 in the southern Peninsular Ranges between Lakeside and Descanso, with respect to bench mark T61, Lakeside. Survey routes and bench mark locations shown in fig. 23.

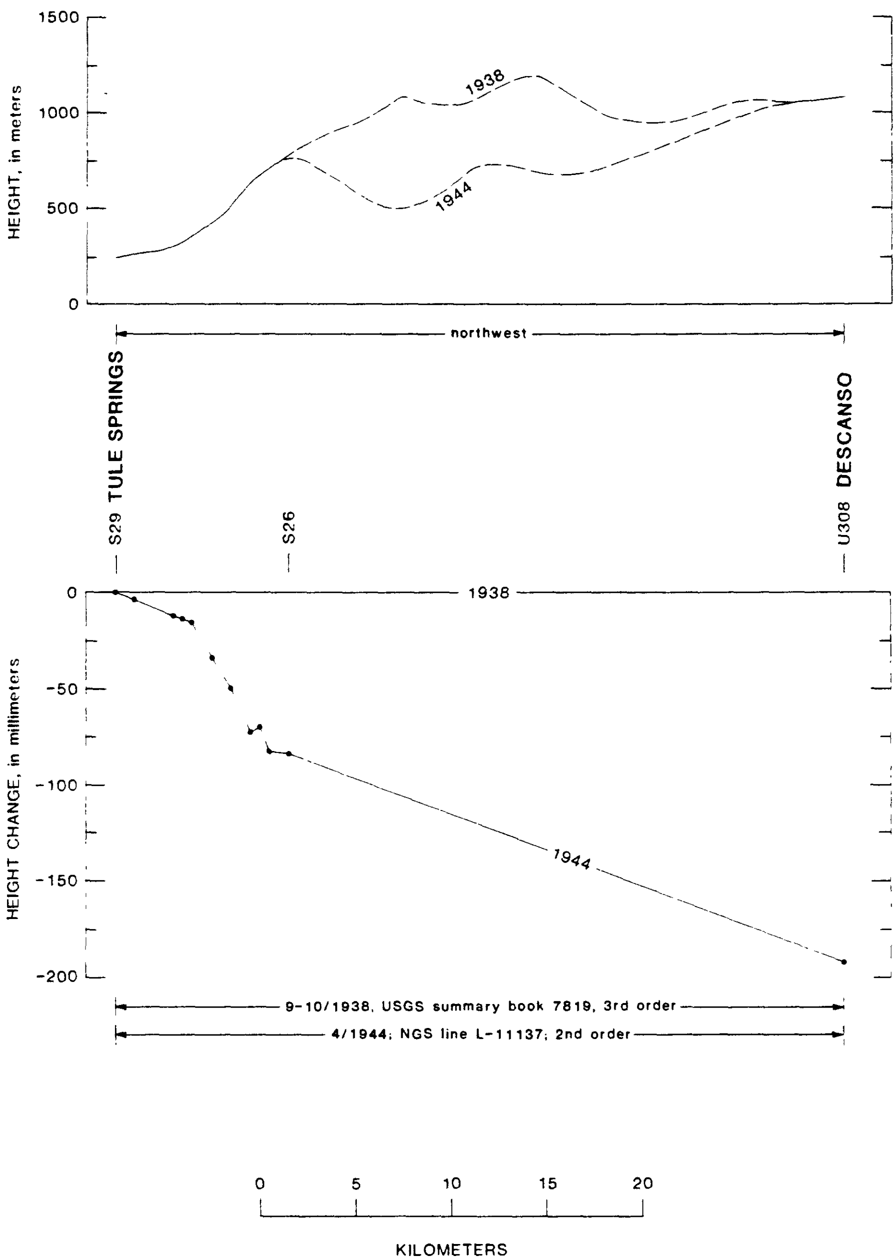


Figure 26. Profiles showing terrain and height changes during the period 1938-1944 in the southern Peninsular Ranges between Tule Springs and Descanso, with respect to bench mark S29, Tule Springs. Survey routes and bench mark locations shown in fig. 23.

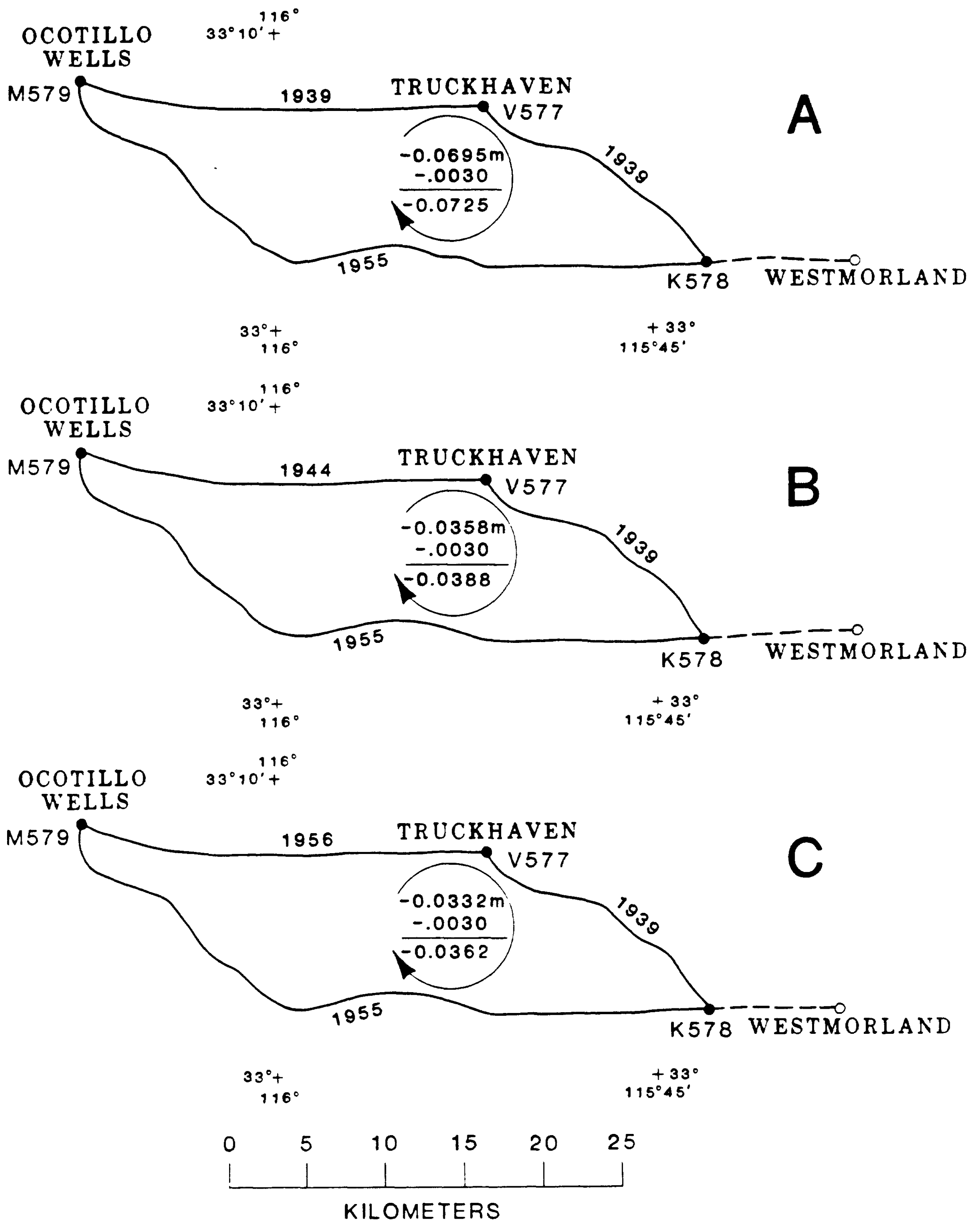


Figure 27. Misclosures around the Ocotillo Wells-Truckhaven-Westmorland-Ocotillo Wells circuit based on various combinations of levelings. A 1939/1955. B 1939/1944/1955. C 1939/1955/1956. 1955 survey run to third-order standards; 1939 and 1944 levelings run to second-order standards; 1956 survey is first-order.

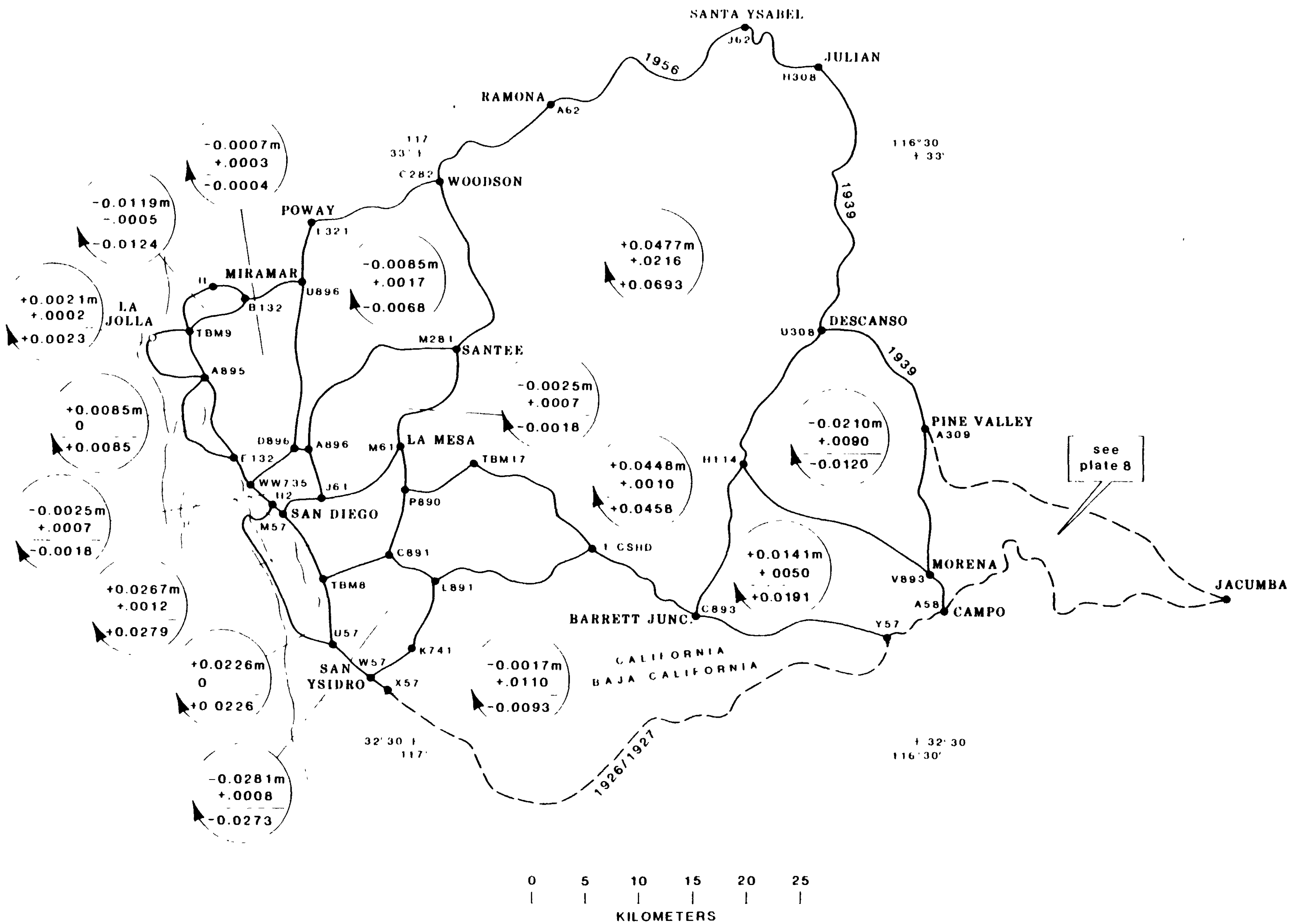


Figure 28. Network and circuit misclosures based on first- and second-order 1955/1956 levelings in the southern Peninsular Ranges. Levelings completed in 1955, unless otherwise designated.

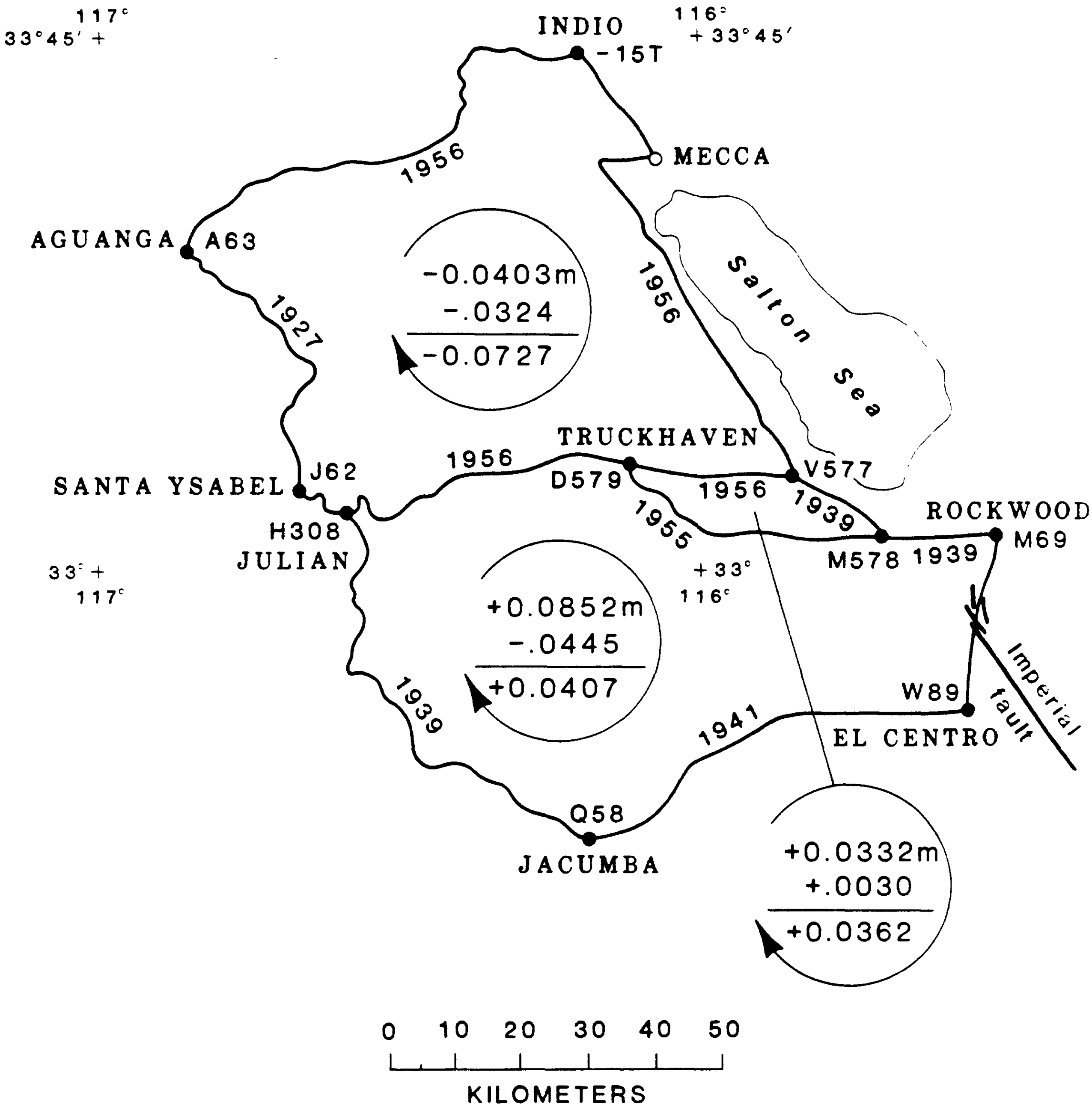


Figure 29. Misclosures around the 1927/1956 circuit Santa Ysabel-Aguanga-Indio-Mecca-Truckhaven-Julian-Santa Ysabel, the 1939/1955/1956 Truckhaven area circuit (see also fig. 27c), and the 1939/1941/1955/1956 circuit Julian-Ocotillo Wells-Westmorland-Rockwood-El Centro-Jacumba-Julian. The closure around the southern circuit is reduced to -0.0282 m if a correction is made for approximately 0.07 m of continuing postseismic movement along the northern Imperial fault between Rockwood and El Centro during the period 1941-1955 (see text and fig. 31 for details).

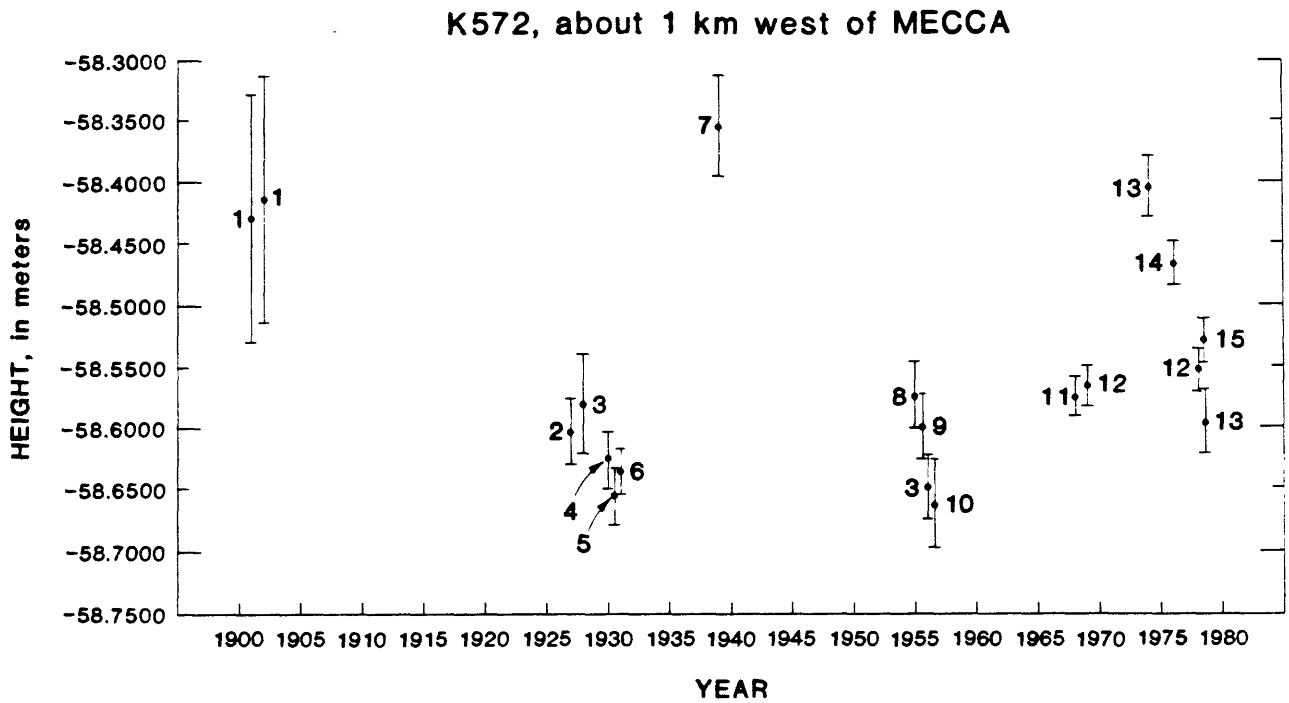


Figure 30. Changes in orthometric height at bench mark K572, about 1 km west of Mecca, with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via San Pedro, Los Angeles, and Colton
2 via Jacumba, El Centro, and Niland
3 via La Mesa, Santa Ysabel, Aguanga, and Indio
4 via Hassayampa, Salome, Blythe, Ogilby, El Centro, and Niland
5 via Hassayampa, Salome, Blythe, Ogilby, and Niland
6 via Bill Williams River, Freda Junction, and Cottonwood Pass
7 via Santa Ysabel, Julian, and Truckhaven
8 via La Mesa, Santa Ysabel, Julian, and Truckhaven
9 via Miramar, Santa Ysabel, Julian, and Truckhaven
10 via Miramar, Santa Ysabel, Aguanga, and Indio
11 via San Ysidro, Campo, Julian, and Salton City
12 via Miramar, Santa Ysabel, Julian, and Salton City
13 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, and Cottonwood Pass
14 via Bill Williams River, Freda Junction, and Cottonwood Pass
15 via Miramar, Julian, Ocotillo, El Centro, and Niland.

Reconstructions outlined in detail in Appendix, Tables E1-E20, and Table 4. Error bars show one standard deviation value for estimated random error only.

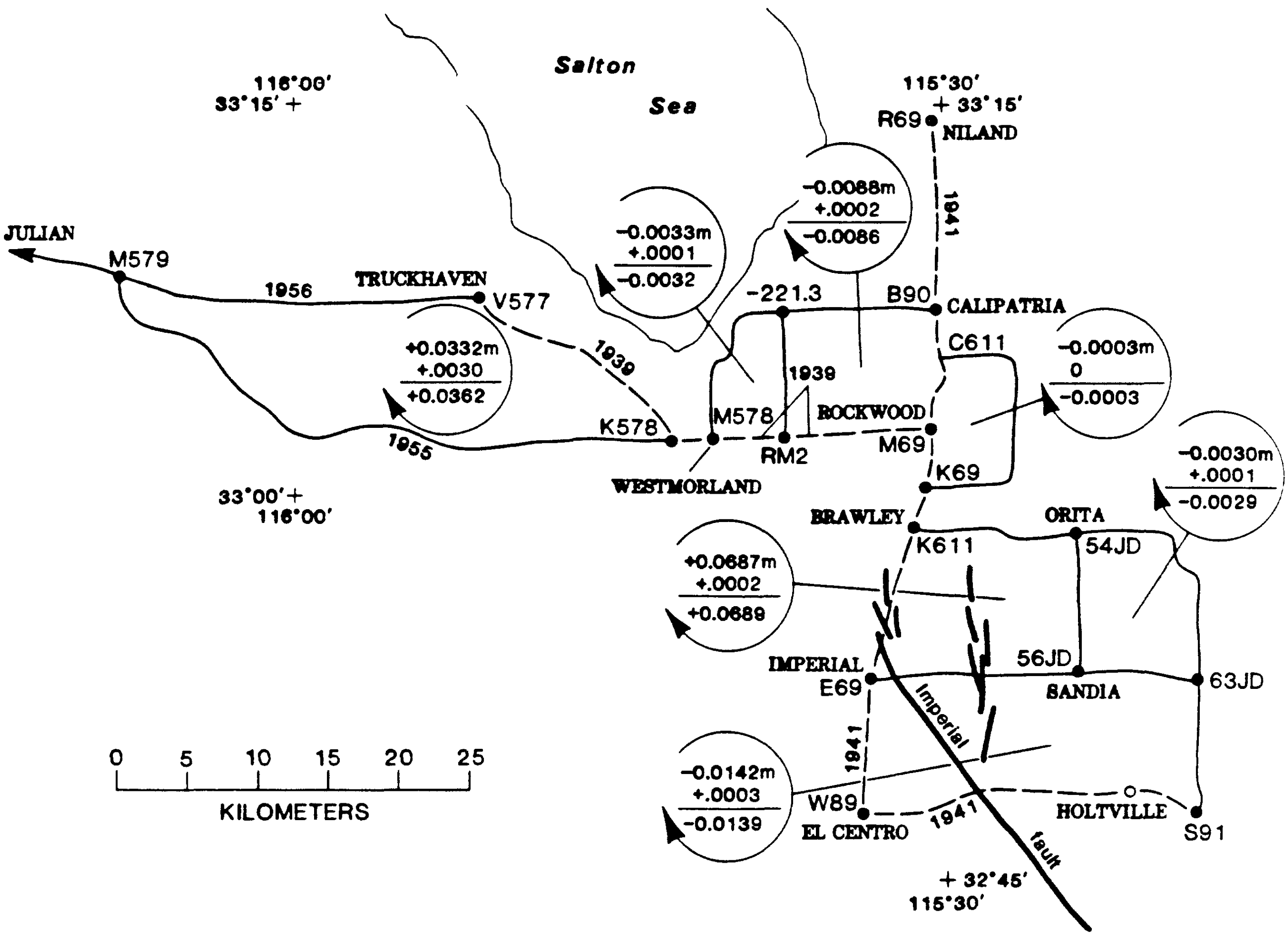


Figure 31. Network and circuit misclosures based on 1955 third-order levelings in the Imperial Valley. These "1955' misclosures are developed against surveys completed in 1939 (between Truckhaven and Rockwood) and 1941 (between Niland via Rockwood and El Centro to bench mark S91, about 5 km east of Holtville), shown as dashed lines. Levelings completed in 1955, unless otherwise designated. 1939 survey run to second-order standards; 1941 and 1956 levelings are first-order.

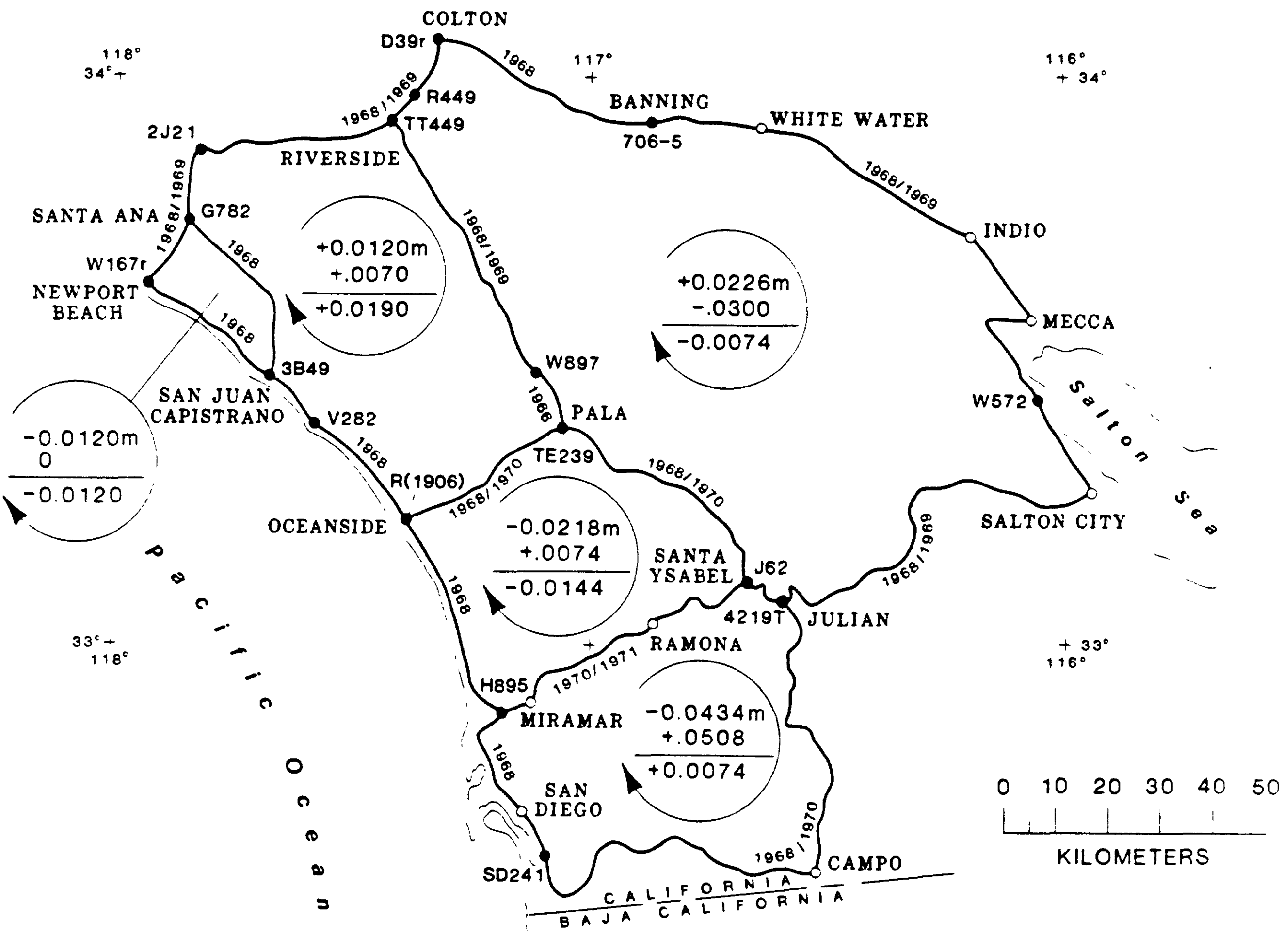


Figure 32. Network and circuit misclosures based on 1968/1969/1970/1971 first-order levelings in southeastern California.

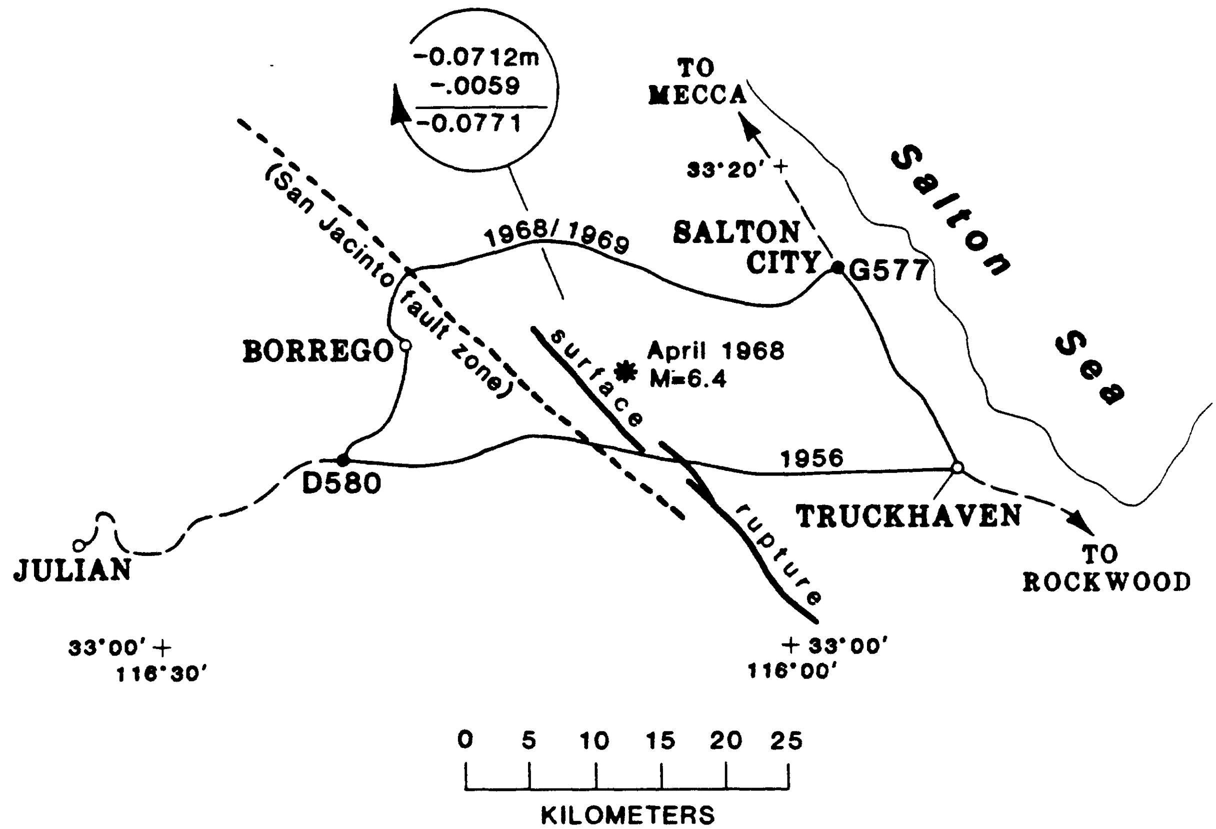


Figure 33. Misclosure around the 1956/1968/1969 circuit Borrego-Salton City-Truckhaven-Borrego. This circuit straddles the historically active southern San Jacinto fault zone, including strands that ruptured during the April 1968 M = 6.4 Borrego Mountain earthquake (surface ruptures and epicenter from Hileman and others, 1973, fig. 61). Although the apparent vertical offset across this fault has increased progressively through time (table 5), the magnitude of this misclosure indicates that most of the signal revealed by comparisons given in table 5 actually developed between 1956 and 1968/1969.

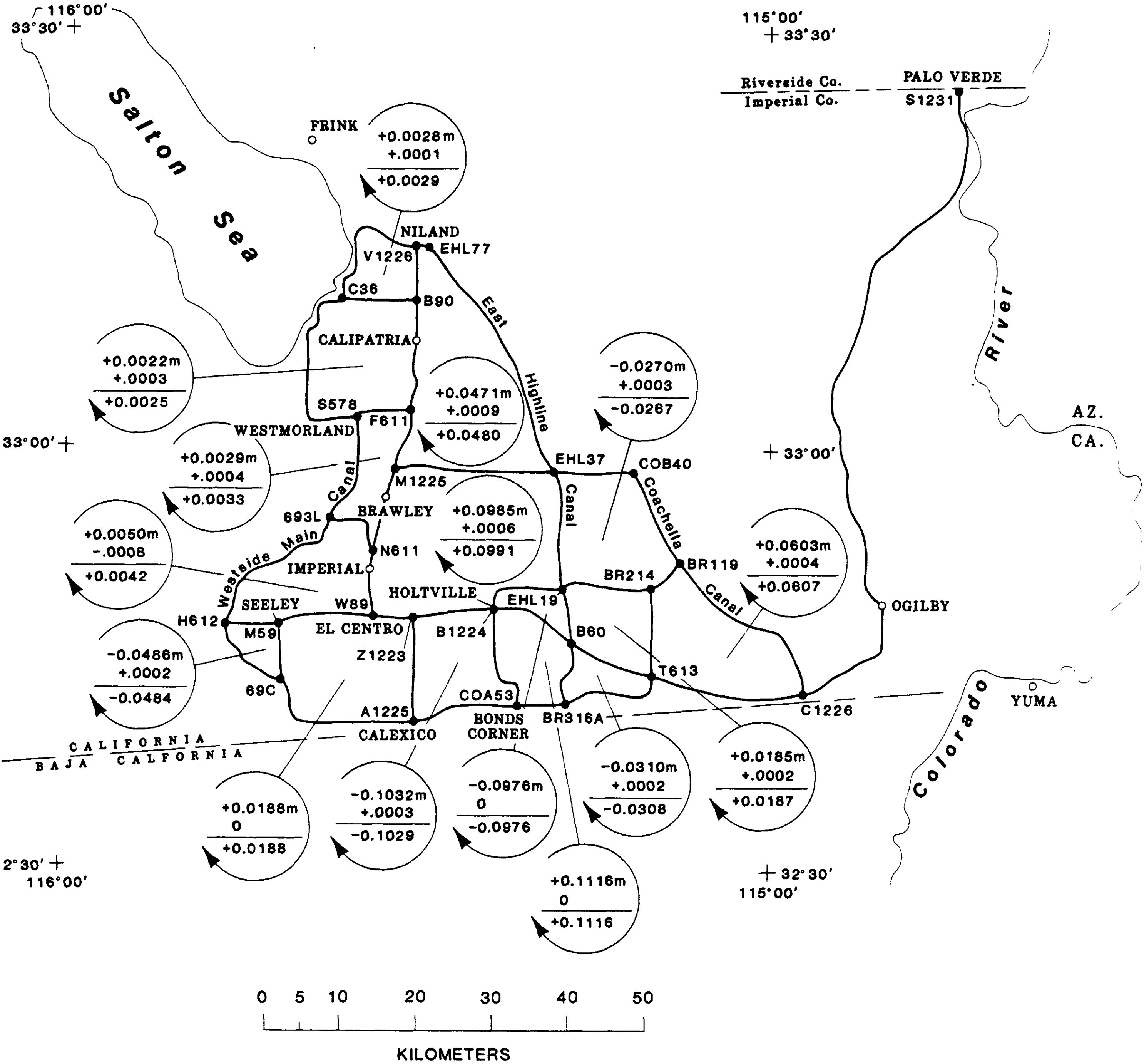


Figure 34. Network and circuit misclosures based on 1971/1972 first- and second-order levelings in the Imperial Valley area.

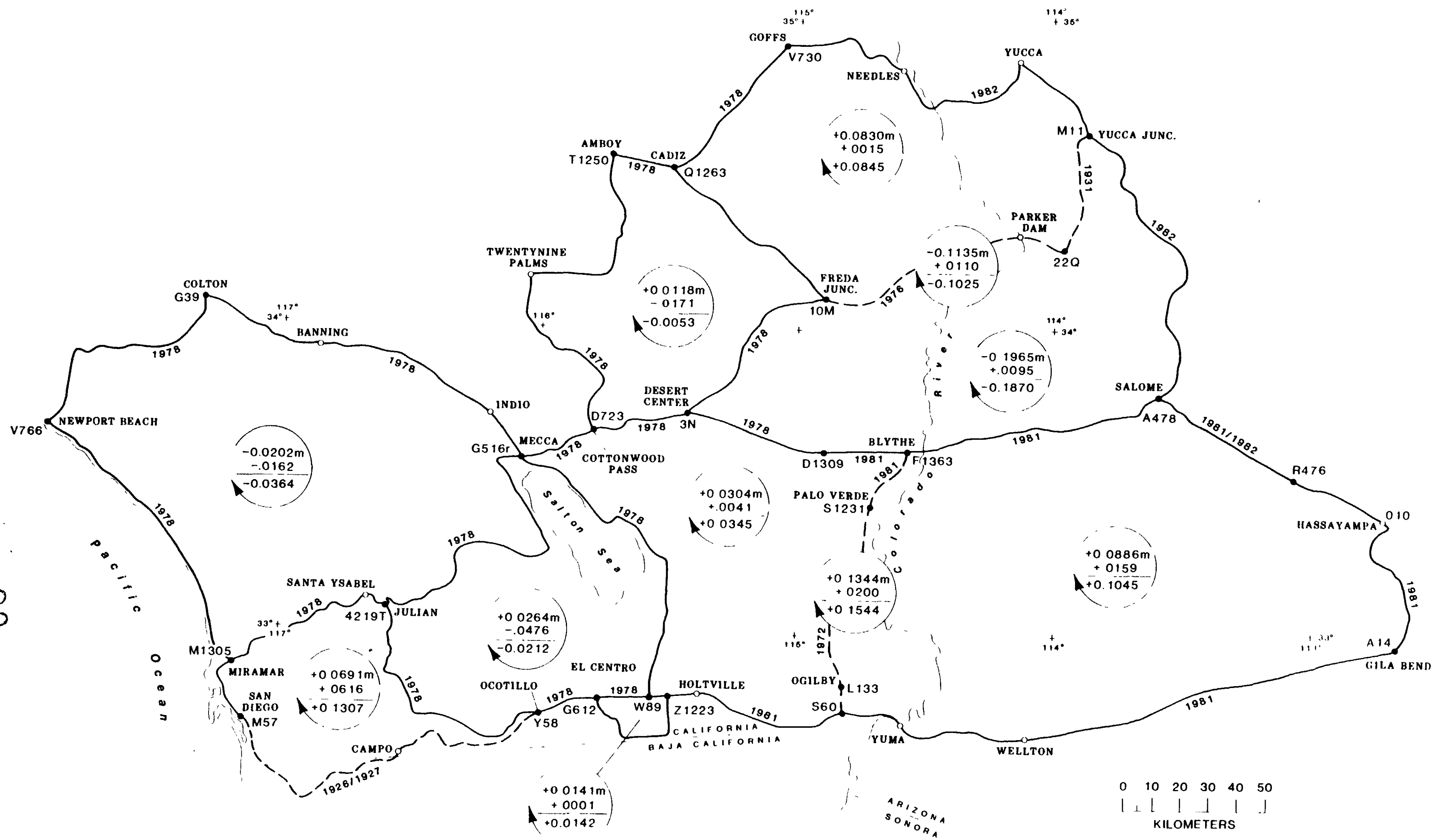


Figure 35. Network and circuit misclosures based on 1978/1981/1982 first-order levelings in southeastern California and southwestern Arizona.

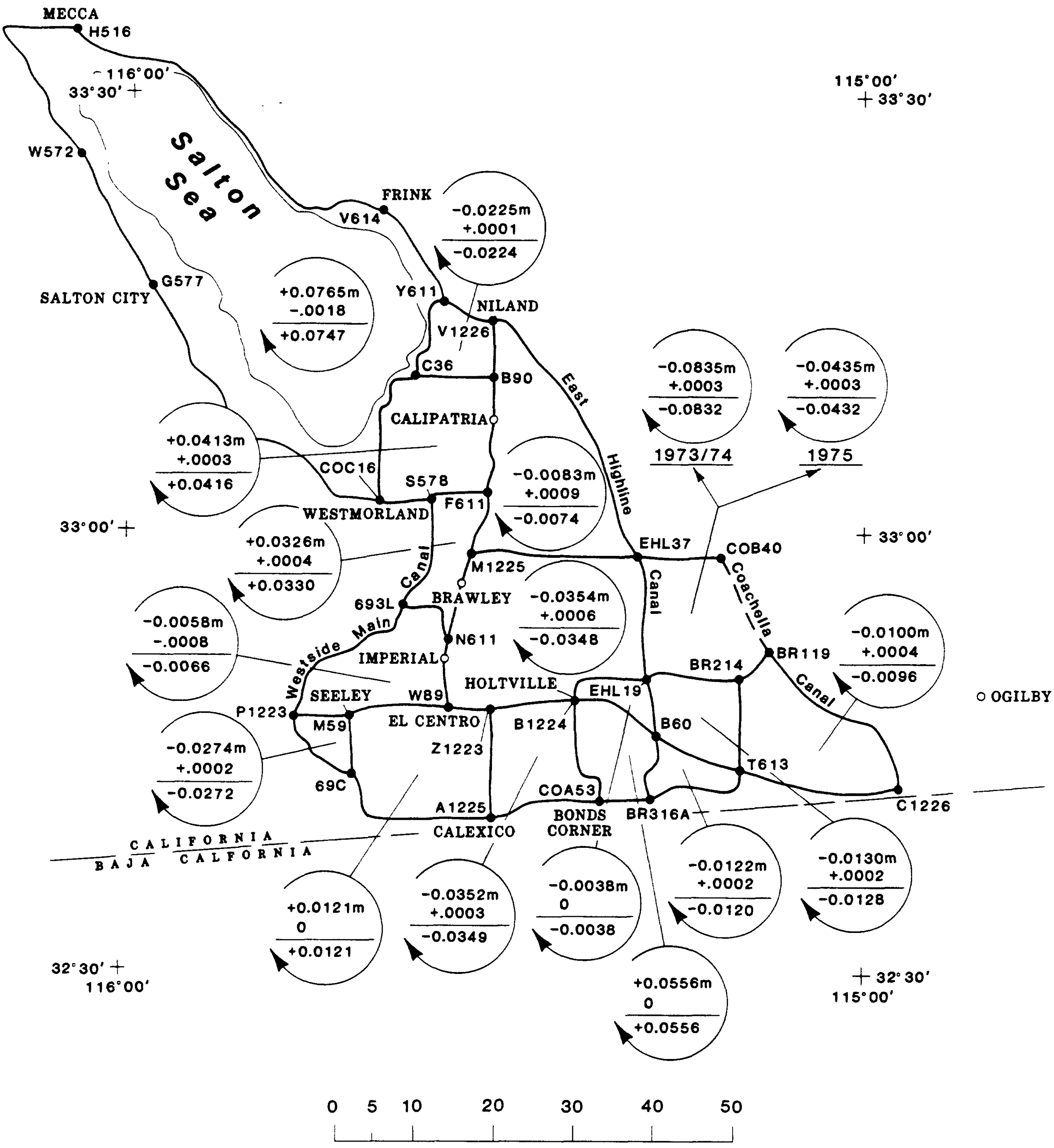


Figure 36. Network and circuit misclosures based on 1973/1974 first- and second-order levelings in the Imperial Valley and Salton Sea area. Dashed-line segment along Coachella Canal run in 1975 as well as 1973/1974, with resulting misclosures shown above.

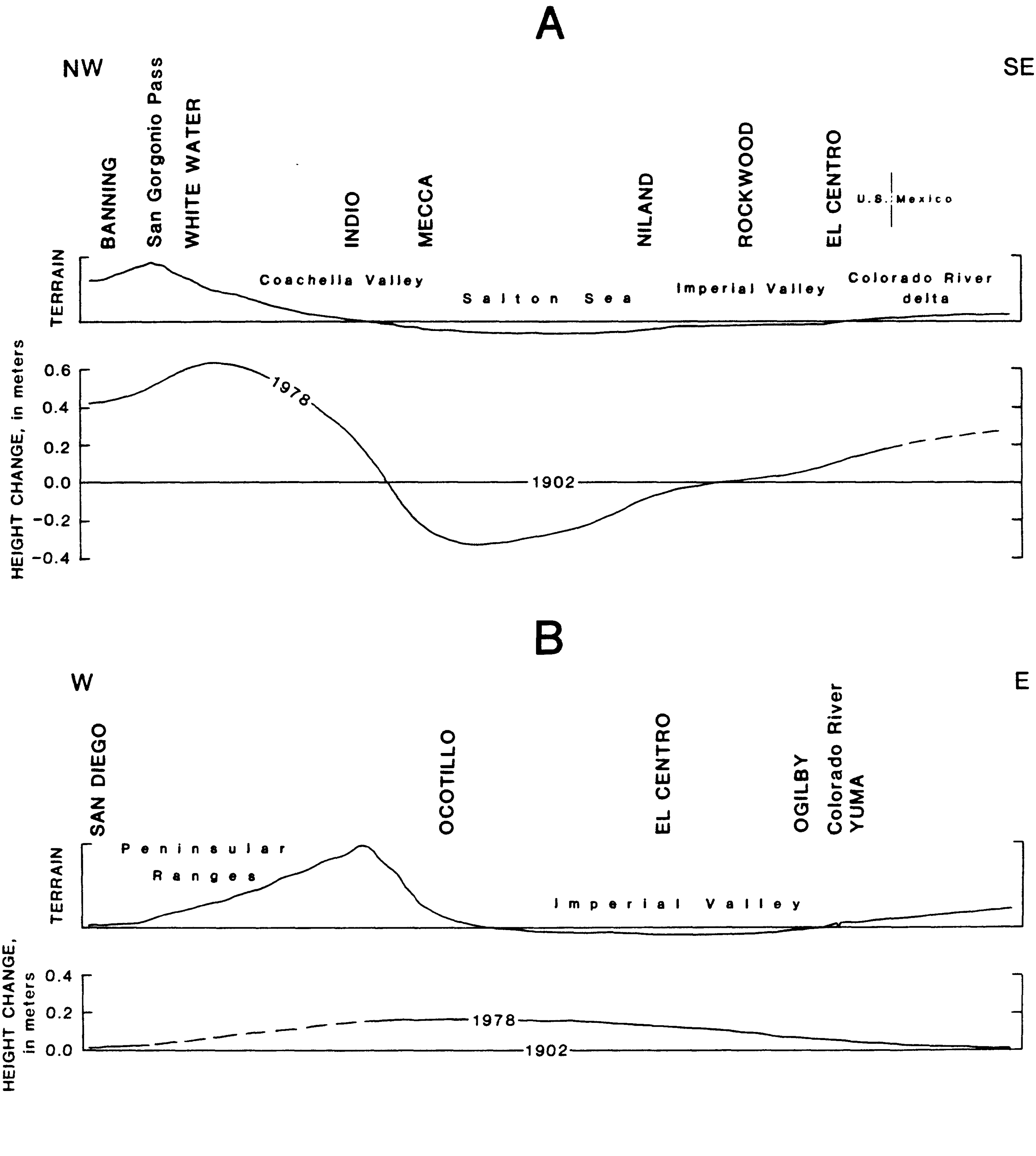


Figure 37. Generalized profiles showing historic trends of height changes A along the axis of the Salton Trough between about San Gorgonio Pass and the International boundary, and B across the Imperial Valley near the latitude of El Centro.

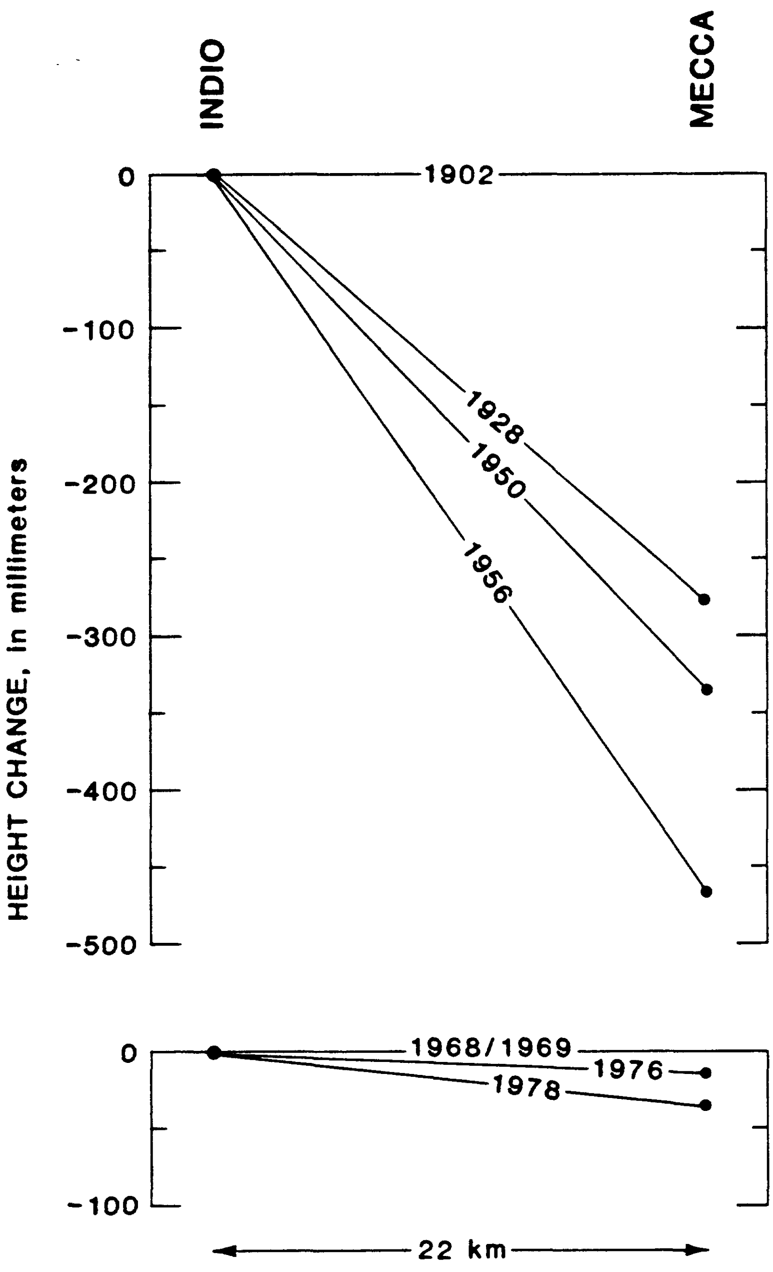


Figure 38. Generalized profiles showing progressive increases in relative height differences between representative bench marks at Indio and Mecca.

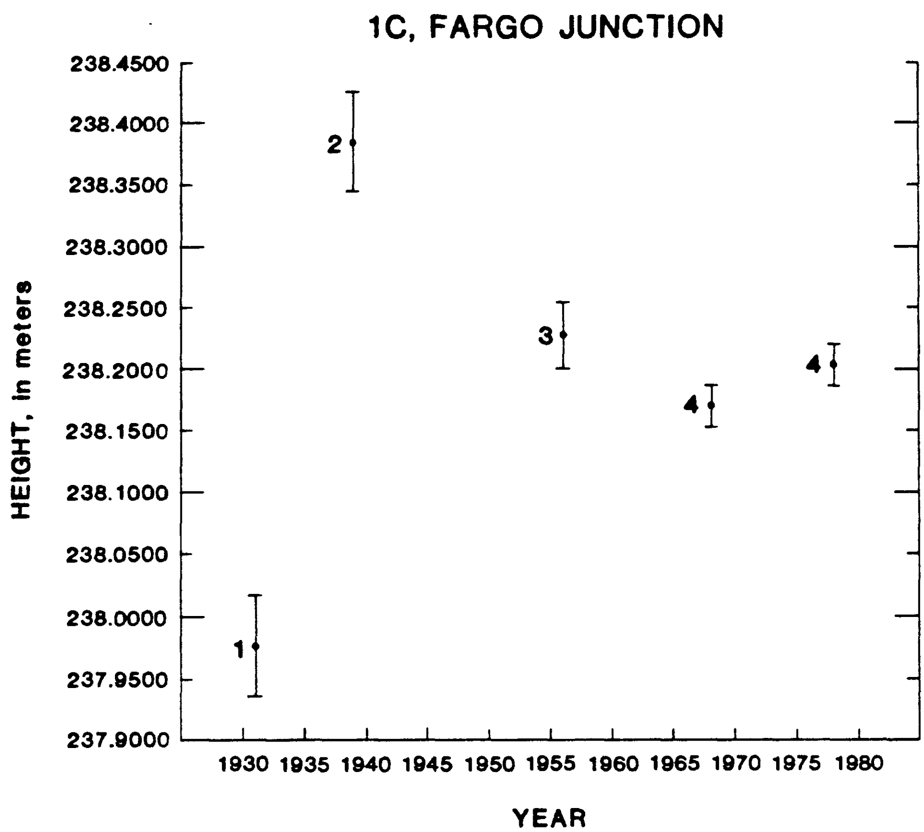


Figure 39. Changes in orthometric height at bench mark 1C, Fargo Junction (about 12 km northeast of Indio), with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via Bill Williams River, Freda Junction, and Cottonwood Pass
2 via Santa Ysabel, Julian, Truckhaven, Mecca, and Indio
3 via Miramar, Julian, Truckhaven, Mecca, and Indio
4 via Miramar, Julian, Salton City, Mecca, and Indio.

Reconstructions based on ties between successively repeated levelings from Indio to Fargo Junction and the primary Indio height (see text and Table 8 for details). Error bars show one standard deviation value for estimated random error only.

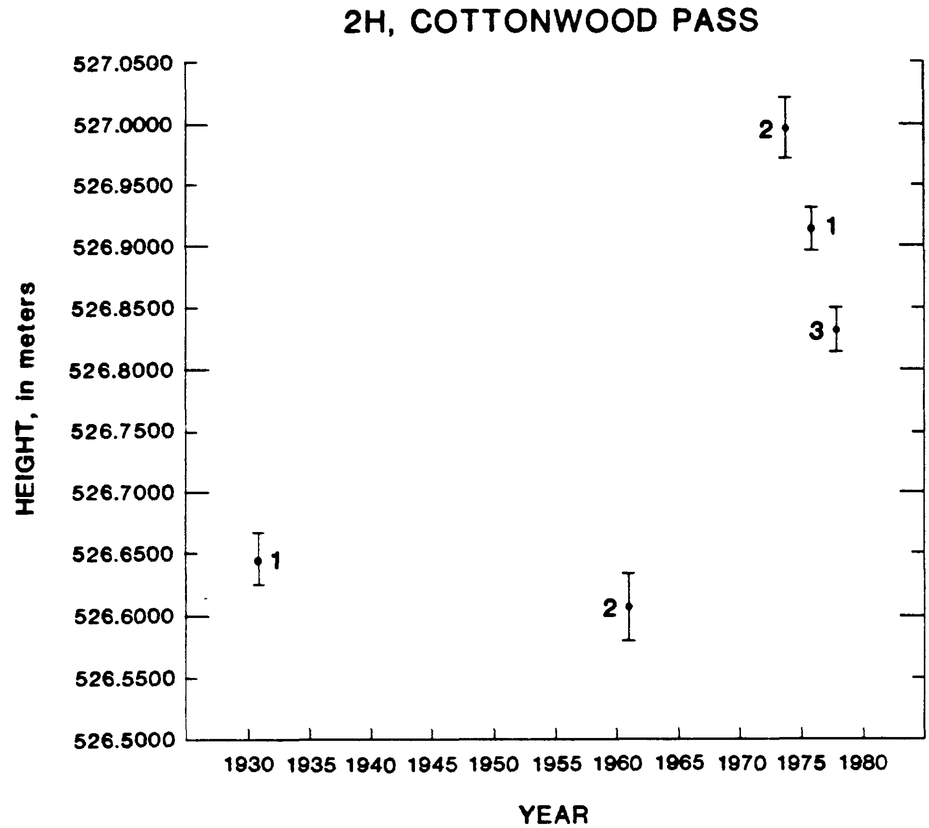


Figure 40. Changes in orthometric height at bench mark 2H, Cottonwood Pass (about 35 km northeast of Mecca), with respect to bench mark M57, San Diego. Based on levelings along the following routes:

1 via Bill Williams River, Freda Junction, and Desert Center
2 via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, and Twentynine Palms
3 via Miramar, Julian, Salton City, and Mecca

Reconstructions outlined in detail in Appendix, Tables L1-L5. Error bars show one standard deviation value for estimated random error only.

APPENDIX

Height reconstructions and supporting data for representative bench marks included in this report.

This appendix consists chiefly of 145 tables that describe and document the reconstructions of a series of heights for a number of representative bench marks within the Salton Trough and some adjoining parts of southeastern California. These reconstructions form the basis for the 14 representative vertical displacement histories for bench marks considered elsewhere in this report (Table 10). Height determinations for any individual bench mark in any given time period are developed from as wide a variety of alternative and independent routes as possible. Due to the limited life span of many (especially early) bench marks, the development of more complete vertical displacement histories depends in some cases on ties to the nearest available common mark and an assumption of invariance between the two.

All of the heights referred to in this report are reconstructed with respect to bench mark M57, a virtually invariant reference mark adjacent to the San Diego tide station (pl. 1). The record height of M57 is given as 5.8830 m, above mean sea-level—effectively local mean sea-level (LMSL) at San Diego (USC and GS quad 321171, line 117). Several reconstructions originate at other demonstrably stable control points with respect to M57 in southwestern Arizona, including bench marks 22Q, Bill Williams River (Tables A1-A4), and 010, Hassayampa (Tables B1-B4). These alternative starting heights are based on the mean value of the separately determined heights derived entirely from first-order levelings (Tables A1-A4, B2-B4) and a demonstrated invariance of both southwestern Arizona reference marks with respect to bench mark M57, San Diego. Reconstructions emanating from these southwestern Arizona bench marks are based on mean starting heights of 186.7030 m at the Bill Williams River bench mark and 274.5661 m at the Hassayampa bench mark, respectively. (Inclusion of the less accurate early 20th-century, third-order reconstruction for Hassayampa (Table B1) would decrease its mean value by less than 0.008 m.) Reconstructions of 1939 heights for representative Salton Trough bench marks depend on an averaged 1938 starting height of 909.6475 m for Santa Ysabel, which is computed as the mean of the 8 alternative 1938/1939 Santa Ysabel heights (Tables J2-J9).

Unless otherwise specified, all reconstructed heights are based exclusively on the results of first-order levelings. The observed elevation differences given by to the National Geodetic Survey have been drawn from traditionally corrected archival data (summary sheets) of the National Geodetic Survey; none have been taken from the machine-readable file for California (National Geodetic Survey, 1978), since these data are known to be contaminated owing to the use of improperly computed values for the rod excess (Mark and others, 1981, p. 2788-2790). The orthometric corrections required to convert path-dependent observed elevation differences into uniquely defined true height differences (independent of survey route) are in all cases based on observed gravity rather than theoretical or normal values. Nearly all of the orthometric corrections are machine-integrated results computed from the observed (or interpolated) gravity values given in the machine-readable data base for California (National Geodetic Survey, 1978). Locally in southern California and throughout Arizona, where machine-readable data are unavailable, orthometric corrections have been computed through the use of a manual technique developed by Petr Vanicek (Castle and others, 1984, p. 23-24), which in turn depends on Bouguer gravity values.

Each of the individual reconstructions for each bench mark height is detailed in the accompanying tables of this appendix. These tables are so arranged that the reader can readily identify the route used in each reconstruction (the number in parantheses following the route description identifies its plotted position in the appropriate vertical displacement history), the data source (by NGS line number, unless otherwise specified), inclusive dates of leveling between marks, the junction bench marks used in the reconstruction, the observed elevation difference between junction bench marks, and the corresponding orthometric correction. Both the conventionally corrected observed elevation differences and the associated orthometric corrections are separately summed for each determination; the algebraic sum of these sums is the orthometrically corrected height for the indicated mark for the indicated period. Where the reconstruction of any of these heights has required the acceptance of certain assumptions, this is explicitly indicated in the accompanying footnotes.

DETAILED INDEX

A. 22Q, Bill Williams River

- A1. 1906, via Santa Ana, Colton, Barstow, Goffs, and Yucca Junction
- A2. 1927, via El Centro, Yuma, Hassayampa, Salome, and Yucca Junction
- A3. 1938, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, and Freda Junction
- A4. 1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, and Freda Junction

B. 010, Hassayampa

- B1. 1902, via San Pedro, Los Angeles, Colton, Mecca, Yuma, and Gila Bend
- B2. 1927, via El Centro, Yuma, and Gila Bend
- B3. 1978, via El Centro, Freda Junction, Bill Williams River, and Salome
- B4. 1981, via El Centro, Yuma, and Gila Bend

C. 1130, White Water

- C1. 1898, via San Pedro, Los Angeles, and Colton
- C2. 1906, via Oceanside, Santa Ana, and Colton
- C3. 1927, via Jacumba, El Centro, Niland, and Mecca
- C4. 1928, via San Pedro, Los Angeles, and Colton
- C5. 1931, via San Pedro, Los Angeles, Riverside, San Jacinto, and Banning
- C6. 1931, via San Pedro, Santa Ana, Riverside, San Jacinto, and Banning
- C7. 1931, via Bill Williams River, Freda Junction, Cottonwood Pass, and Indio
- C8. 1932, via Oceanside, Santa Ana, Riverside, San Jacinto, and Banning
- C9. 1932, via Oceanside, Aguanga, San Jacinto, and Banning
- C10. 1968, via San Ysidro, Campo, Julian, Salton City, and Mecca
- C11. 1969, via Miramar, Julian, Salton City, and Mecca
- C12. 1976, via Bill Williams River, Freda Junction, Cottonwood Pass, and Mecca
- C13. 1978, via Miramar, Julian, Salton City, and Mecca
- C14. 1978, via Miramar, Julian, El Centro, Niland, and Mecca
- C15. 1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca

D. -15T, Indio

- Dl. 1901, via San Pedro, Los Angeles, and Colton
- D2. 1902, via San Pedro, Los Angeles, and Colton
- D3. 1927, via La Mesa Santa Ysabel, and Aguanga
- D4. 1928, via Jacumba, El Centro, Niland, and Mecca
- D5. 1930, via Hassayampa, Salome, Blythe, Ogilby, El Centro, Niland, and Mecca
- D6. 1930, via Hassayampa, Salome, Blythe, Ogilby, Niland, and Mecca
- D7. 1931, via Bill Williams River, Freda Junction, Cottonwood Pass, and Fargo Junction
- D8. 1932, via San Pedro, Los Angeles, and Riverside
- D9. 1932, via Oceanside, Aguanga, San Jacinto, Banning, and White Water
- D10. 1939, via Santa Ysabel, Julian, Truckhaven, and Mecca
- D11. 1955, via La Mesa, Julian, Truckhaven, and Mecca
- D12. 1955, via Miramar, Julian, Truckhaven, and Mecca
- D13. 1956, via La Mesa, Santa Ysabel, and Aguanga

D14. 1956, via Miramar, Santa Ysabel, and Aguanga
D15. 1968, via Santa Ysabel, Campo, Julian, Salton City, and Mecca
D16. 1969, via Miramar, Santa Ysabel, Julian, Salton City, and Mecca
D17. 1976, via Bill Williams River, Freda Junction, Cottonwood Pass, and Mecca
D18. 1978, via Miramar, Julian, Ocotillo, El Centro, Niland, and Mecca
D19. 1978, via Miramar, Santa Ysabel, Julian, Salton City, and Mecca
D20. 1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca

E. <u>G516 and K572, Mecca</u>

E1. 1901, via San Pedro, Los Angeles, and Colton
E2. 1902, via San Pedro, Los Angeles, and Colton
E3. 1927, via Jacumba, El Centro, and Niland
E4. 1928, via La Mesa, Santa Ysabel, Aguanga, and Indio
E5. 1930, via Hassayampa, Salome, Blythe, Ogilby, El Centro, and Niland
E6. 1930, via Hassayampa, Salome, Blythe, Ogilby, and Niland
E7. 1931, via Bill Williams River, Freda Junction, and Cottonwood Pass
E8 1939, via Santa Ysabel, Julian, and Truckhaven
E9. 1955, via La Mesa, Santa Ysabel, Julian, and Truckhaven
E10. 1955, via Miramar, Santa Ysabel, Julian, and Truckhaven
E11. 1956, via La Mesa, Santa Ysabel, Aguanga, and Indio
E12. 1956, via Miramar, Santa Ysabel, Aguanga, and Indio
E13. 1968, via Santa Ysabel, Campo, Julian, and Salton City
E14. 1969, via Miramar, Santa Ysabel, Julian, and Salton City
E15. 1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, and Cottonwood Pass
E16. 1976, via Bill Williams River, Freda Junction, and Cottonwood Pass
E17. 1978, via Miramar, Julian, and Salton City
E18. 1978, via Miramar, Julian, Ocotillo, El Centro, and Niland
E19. 1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, and Cottonwood Pass

F. <u>G577, Salton City</u>

F1. 1939, via Santa Ysabel, Julian, and Truckhaven
F2. 1955, via La Mesa, Ramona, Julian, and Truckhaven
F3. 1955, via Miramar, Ramona, Julian, and Truckhaven
F4. 1956, via Miramar, Santa Ysabel, Aguanga, Indio, and Mecca
F5. 1968, via Campo, Julian, and Borrego
F6. 1969, via Miramar, Julian, and Borrego
F7. 1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca
F8. 1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, Mecca, Niland, Rockwood, and Truckhaven
F9. 1978, via Miramar, Julian, El Centro, and Borrego
F10. 1978, via Miramar, Julian, El Centro, and Mecca

G. R69, Niland

- G1. 1927, via Jacumba and El Centro
- G2. 1939, via Santa Ysabel, Truckhaven, and Rockwood
- G3. 1955, via Miramar, Ramona, Julian, Truckhaven, and Rockwood
- G4. 1956, via La Mesa, Ramona, Julian, Truckhaven, and Rockwood
- G5. 1972, via Hassayampa, Salome, Blythe, Palo Verde, Ogilby, and El Centro
- G6. 1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca
- G7. 1976, via Bill Williams River, Freda Junction, Cottonwood Pass, and Mecca
- G8. 1978, via Miramar, Julian, Ocotillo, and El Centro
- G9. 1978, via Miramar, Julian, Salton City, and Mecca
- G10. 1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca

H. -162Y, Rockwood

- H1. 1904, via San Pedro, Los Angeles, Colton, Mecca, and Old Beach
- H2. 1905, via San Pedro, Los Angeles, Colton, Mecca, and Old Beach
- H3. 1927, via Jacumba and El Centro
- H4. 1928, via La Mesa, Santa Ysabel, Aguanga, Indio, and Niland
- H5. 1938, via Santa Ysidro, Campo, Pine Valley, Jacumba, and El Centro
- H6. 1939, via Santa Ysabel, Julian, and Truckhaven
- H7. 1955, via Miramar, Ramona, Julian, and Truckhaven
- H8. 1956, via La Mesa, Ramona, Julian, and Truckhaven
- H9. 1972, via Hassayampa, Salome, Blythe, Palo Verde, Ogilby, and El Centro
- H10. 1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, Mecca, and Salton City
- H11. 1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, Mecca, and Niland
- H12. 1976, via Bill Williams River, Freda Junction, Cottonwood Pass, Mecca, and Niland
- H13. 1978, via Miramar, Julian, Ocotillo, and El Centro
- H14. 1978, via Miramar, Julian, Salton City, Mecca, and Niland
- H15. 1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, Mecca, and Niland

I. R59, El Centro

- I1. 1904, via San Pedro, Los Angeles, Colton, Mecca, and Old Beach
- I2. 1905, via San Pedro, Los Angeles, Colton, Mecca, and Old Beach
- I3. 1927, via San Ysidro, Campo, and Ocotillo
- I4. 1935, via Santa Ysabel, Julian, Pine Valley, and Jacumba
- I5. 1938, via San Ysidro, Campo, Pine Valley, and Jacumba
- I6. 1939, via Santa Ysabel, Julian, Pine Valley, and Jacumba
- I7. 1939, via Santa Ysabel, Julian, Truckhaven, and Rockwood
- I8. 1955, via San Ysidro, Campo, Pine Valley, and Jacumba
- I9. 1956, via La Mesa, Julian, Truckhaven, and Rockwood
- I10. 1972, via Hassayampa, Salome, Blythe, Palo Verde, and Ogilby
- I11. 1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, Mecca, and Niland
- I12. 1976, via Bill Williams River, Freda Junction, Cottonwood Pass, Mecca, and Niland
- I13. 1978, via Miramar, Julian, and Ocotillo

I14. 1978, via Miramar, Julian, Salton City, Mecca, and Niland
I15. 1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Ambov, Twentynine Palms, Cottonwood Pass, Mecca, and Niland
I16. 1981, via Hassayampa and Yuma

J. J62, Santa Ysabel

J1. 1927, via La Mesa and Ramona
J2. 1938, via Grantville, Poway, Ramona, Barona Valley, Tule Springs, and Julian
J3. 1938, via Grantville, Santee, Poway, Ramona, Barona Vallev, Tule Springs, and Julian
J4. 1938, via Grantville, Santee, Lakeside, Barona Vallev, Tule Springs, and Julian
J5. 1939, via La Mesa, Jamul, Dulzura, Barrett Junction, Campo, Pine Vallev, and Julian
J6. 1939, via National City, La Presa, Jamul, Dulzura, Barrett Junction, Campo, Pine Vallev, and Julian
J7. 1939, via Chula Vista, Jamul, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian
J8. 1939, via Chula Vista, Otay Dam, Kuebler Ranch, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian
J9. 1939, via San Ysidro, Kuebler Ranch, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian
J10. 1955, via Miramar and Ramona
J11. 1956, via La Mesa and Ramona
J12. 1968, via San Ysidro, Campo, and Julian
J13. 1969, via Miramar and Ramona
J14. 1969, via Oceanside and Pala
J15. 1978, via Miramar and Ramona

K. Y57, near Campo

K1. 1901, via Otay, Jamul, and Potrero
K2. 1902, via Otay, Jamul, and Potrero
K3. 1927, via San Ysidro, and northern Baja California
K4. 1938, via La Mesa, Jamul, Dulzura, and Barrett Junction
K5. 1938, via National City, La Presa, Jamul, Dulzura, and Barrett Junction
K6. 1938, via Chula Vista, Jamul, Dulzura, and Barrett Junction
K7. 1938, via Chula Vista, Otay Dam, Kuebler Ranch, Dulzura,, and Barrett Junction
K8. 1938, via San Ysidro, Kuebler Ranch, Dulzura, and Barrett Junction
K9. 1955, via San Ysidro, Dulzura, and Barrett Junction
K10. 1968, via San Ysidro, Dulzura, and Barrett Junction
K11. 1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Ambov, Twentynine Palms, Cottonwood Pass, Mecca, Niland, El Centro, and Pine Vallev
K12. 1978, via Miramar, Julian, and Pine Vallev

L. 2H, Cottonwood Pass

- L1. 1931, via Bill Williams River, Freda Junction, and Desert Center
- L2. 1961, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, and Twentynine Palms
- L3. 1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, and Twentynine Palms
- L4. 1976, via Bill Williams River, Freda Junction, and Desert Center
- L5. 1978, via Miramar, Julian, Salton City, and Mecca

1C. Fargo Junction

1. 1931, via Bill Williams River, Freda Junction, and Cottonwood Pass
2. 1939, via Santa Ysabel, Julian, Truckhaven, Mecca, and Indio
3. 1956, via Miramar, Julian, Truckhaven, Mecca, and Indio
4. 1968, via Miramar, Julian, Salton City, Mecca, and Indio
5. 1978, via Miramar, Julian, Salton City, Mecca, and Indio

TABLE A1. BILL WILLIAMS RIVER
1906, via Santa Ana, Colton, Barstow, Goffs, and Yucca (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego area	82606	12/1926-3/27	M57 - 42SD	+6.9649	0.0000
San Diego - Barstow	USC, and GS Spec. Pub. 18	3-6/1906	42SD - H3	+627.7523	-0.0635
Barstow - Goffs	P-60540	12/1906-5/07	H3 - L5	+146.0384	+.0722
Goffs - Yucca	P-63613.A	4-9/1909	L5 - P	-235.9400	-.0352
Yucca - Yucca Junc.	82625	1927	P - L11	+377.1889	+.0385
Yucca Junc. - 22Q	L-7407	1931	L11 - 22Q	-741.1874	-.0398
			Sum =	+186.7001	-0.0278
	Orthometrically corrected height for 22Q =			+186.6723 m	

TABLE A2. BILL WILLIAMS RIVER
1927, via Santa Ana, Colton, Barstow, Goffs, and Yucca (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Yuma	82606	12/1926-3/27	M57 - V7	+35.7325	+0.0172
Yuma - Hassayampa	82632	1927	V7 - 010	+232.9231	+.0039
Hassayampa - Yucca	82625	1927	010 - L11	+653.3387	-.0029
Yucca - 22Q	L-7407	1931	L11 - 22Q	-741.1874	-.0398
			Sum =	+186.6899	-0.0216
	Orthometrically corrected height for 22Q =			+186.6683 m	

TABLE A3. BILL WILLIAMS RIVER
1938, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, and Freda Junction (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.3500[1/]	-0.0022
San Pedro - Barstow	82466,82583, 82598,82600, L-1; L-18364, L-18299, L-18296	1926/1927/ 1928; 1961	Tidal 8 - E43	+640.2429[2/]	+.0170
Barstow - Daggett	L-18230	3-4/1961	E43 - G293	-33.2750	-.0001
Daggett - Cadiz	L-11115.A	2-4/1944	G293 - 10A	-382.4137	-.0194
Cadiz - 22Q	L-7407	1931	10A - 22Q	-41.3663	+.0050
			Sum =	+186.7209	+0.0003
	Orthometrically corrected height for 22Q =			+186.7212 m	

Notes:

1/ The 1931/1932/1933 elevation difference between San Diego and San Pedro has been corrected to a 1938-equivalent by allowing for movement known to have occurred along this line both between 1931/1932/1933 and 1938 and during the course of the 1931/1932/1933 leveling. Specifically, a correction has been applied to the 1932/1933 starting height at Santa Ana in order to provide for about 0.01 m of compaction-induced subsidence that occurred at this mark during the 1931/1932-1932/1933 junction interval (Castle and Elliott, 1982, p. 7005). Secondly, relative movement between the San Diego and San Pedro tide stations has been assessed by comparing linear regressions through the 19-yr mean sea level curves at both tide stations. Linear regressions through the post-1934 San Diego tide station records (when the primary San Diego tide station was located at the Municipal Pier along central San Diego Bay) and through the entire series at San Diego indicate that sea level at San Pedro has been declining at about 1.56±0.07 mm/yr with respect to the Municipal Pier (Castle and Elliott, 1982, p. 7010, 7016). Interpretation of this decline in sea level as relative uplift at the San Pedro tide station indicates that the 1938 starting height for bench mark Tidal 8, San Pedro (with respect to M57), was approximately 0.0094-m below its 1931/1932/1933 height.

2/ This elevation difference is based on a proration of the results of both the 1926/1927/1928 and early 1961 levelings between Tidal 8, San Pedro, and E43, Barstow.

1926/1927/1928 =	+640.2487 m
Early 1961 =	+640.2307

Proration of the 0.0180-m subsidence of bench mark E43 during the interval 1926/1927/1928-1961 indicates that the 1938 observed elevation of this mark with respect to Tidal 8 was about 0.0058 m less than its 1926/1927/1928 observed elevation (that is, 640.2429 m), and it is this computed value for E43 that has been used in this reconstruction.

TABLE A4. BILL WILLIAMS RIVER
1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, and Freda Junction (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.B830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.2876[1/]	-0.0022
San Pedro area	L-24301.1	1-5/1978	Tidal 8 - 21-03269	+8.8482	+.0002
San Pedro - Mojave	L-24301.6	1-4/1978	21-03269 - Q49	+835.5896	+.0423
Mojave - Barstow	L-24301.13	1-4/1978	Q49 - GagStn	-203.6716	-.0192
Barstow - Amboy	L-24301.23	1-4/1978	GagStn - T1250	-458.7536	-.0225
Amboy - Freda Junc.	L-24301.28	1-4/1978	T1250 - 10M	+79.4604	+.0068
Freda Junc. - 20W	L-24077	4-5/1976[2/]	10M - 20W	+35.0718	+.0022
20W - 21N	L-24085	9-10/1975[2/]	20W - 21N	+7.0468	+.0008
21N - 22Q	L-24068	5-6/1976[2/]	21N - 22Q	-120.4695	-.0065
			Sum =	+186.7175	+0.0021
	Orthometrically corrected height for 22Q =			+186.7196 m	

Notes:

1/ The 1931/1932/1933 elevation difference between San Diego and San Pedro has been corrected to a 1978-equivalent by allowing for movement known to have occurred along this line both between 1931/1932/1933 and 1978 and during the course of the 1931/1932/1933 leveling. Specifically, a correction has been applied to the 1932/1933 starting height at Santa Ana in order to provide for about 0.01 m of compaction-induced subsidence that occurred at this mark during the 1931/1932-1932/1933 junction interval (Castle and Elliott, 1982, p. 7005). Secondly, relative movements between the San Diego and San Pedro tide stations has been assessed by comparing linear regressions through the 19-yr mean sea level curves at both tide stations. Linear regressions through the post-1934 San Diego tide station records (when the primary San Diego tide station was located at the Municipal Pier along central San Diego Bay) and through the entire series at San Diego indicate that sea level at San Pedro has been declining at about 1.56±0.07 mm/yr with respect to the Municipal Pier (Castle and Elliott, 1982, p. 7010, 7016). Interpretation of this decline in sea level as relative uplift at the San Pedro tide station indicates that the 1978 starting height for bench mark Tidal 8, San Pedro (with respect to M57), was approximately 0.0718-m above its 1931/1932/1933 height.

2/ Comparison of the results of 1978 leveling against a 1976 datum between Freda Junction and Amboy (NGS lines L-24077 and L-24301.28) indicate that this reach remained free of differential movement during the period 1976-1978. Hence, the results of the 1975/1976 levelings between Freda Junction and the Bill Williams River are taken as the equivalent of those that would have been obtained in 1978.

TABLE B1. HASSAYAMPA
1902, via San Pedro, Los Angeles, Colton, Mecca, Yuma, and Gila Bend (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.4062 1/	-0.0022
San Pedro tide station	Castle and others (1986)	--	Tidal 8 - BMA	+3.4248	0.0000
San Pedro - Colton	USGS 19th Ann. Rept. 2/	1897	BMA - 978	+291.3984	+.0170
Colton - Yuma	USGS summary book 9488 2/	10-11/1902	978 - 137	-256.3291	+.0088
Yuma - Gila Bend	63082	1905	137 - A14	+183.3259	+.0063
Gila Bend - Hassayampa	82625	1927	A14 - 010	+49.2170	-.0062
			Sum =	+274.5138	+0.0237
	Orthometrically corrected height for 010 =			+274.5375 m	

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1902-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro between 1902 and 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

2/ Third-order.

TABLE B2. HASSAYAMPA
1927, via El Centro, Yuma, and Gila Bend (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Yuma	82606	12/1926-3/27	M57 - U7	+35.7325	+0.0172
Yuma - Hassayampa	82632	1927	U7 - 010	+232.9231	+.0039
			Sum =	+274.5386	+0.0211
	Orthometrically corrected height for 010 =			+274.5597 m	

– .06

TABLE B3. HASSAYAMPA
1978, via El Centro, Freda Junction, Bill Williams River, and Salome (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Julian El Centro - Mecca	L-24301.18	1-5/1978	M1305 - G516r	-192.4807	+.0782
Mecca - Freda Junc.	L-24301.28	1-4/1978	G516r - 10M	+322.1815	-.0096
Freda Junc. - 20W	L-24077	4-5/1976	10M - 20W	+35.0718	+.0022
20W - 21N	L-24085	9-10/1975	20W - 21N	+7.0468	+.0008
21N - 22Q	L-24068	5-6/1976	21N - 22Q	-120.4695	-.0065
22Q - Yucca Junc.	L-7407	1931	22Q - L11	+741.1874	+.0398
Yucca Junc. area	82625	1927	L11 - M11	+5.9824	.0000
Yucca Junc. - Salome	L-24684	1-2/1982	M11 - A478	-373.2841	+.0084
Salome - Burning Well	L-24562.3	12/1981-1/82	A478 - R476	-184.6105	+.0045
Burning Well - Hassayampa	L-24555.3	3-4/1981	R476 - 010	-101.4902	-.0010
			Sum =	+274.4763	+0.1093
	Orthometrically corrected height for 010 =			+274.5856 m	

TABLE B4. HASSAYAMPA
1981, via El Centro, Yuma, and Gila Bend (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - El Centro	L-24301.18	1-5/1978	M1305 - R59	-147.6152	+.0777
El Centro - Gila Bend	L-24562.1	3-5/1981	R59 - A14	+237.4664	+.0065
Gila Bend - Hassayampa	L-24555.3	3-4/1981	A14 - 010	+49.2808	-.0062
			Sum =	+274.4734	+0.0795
	Orthometrically corrected height for 010 =			+274.5529 m	

TABLE C1. WHITE WATER
1898, via San Pedro, Los Angeles, and Colton (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.4124[1/]	-0.0022
San Pedro tide station	Castle and others (1986)	--	Tidal 8 - BMA	+3.4248	.0000
San Pedro - Colton	USGS 19th Ann. Rept.[2/]	1897	BMA - 978	+291.3984	+.0170
Colton - White Water	USGS summary book 5816[2/]	2-3/1898	978 - 1130	+46.2117	+.0135
			Sum =	+344.5055	+0.0283
	Orthometrically corrected height for 1130 =			+344.5338 m	

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1898-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1898 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

2/ Third-order.

TABLE C2. WHITE WATER
1902, via San Pedro, Los Angeles, and Colton (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.4062[1/]	-0.0022
San Pedro tide station	Castle and others (1986)	--	Tidal 8 - BMA	+3.4248	.0000
San Pedro - Colton	USGS 19th Ann. Rept.[2/]	1897	BMA - 978	+291.3984	+.0170
Colton - White Water	USGS summary book 9488[2/]	10-11/1902	978 - 1130	+46.1955	+.0135
			Sum =	+344.4955	+0.0283
	Orthometrically corrected height for 1130 =			+344.5238 m	

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1902-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1902 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

3/ Third-order.

TABLE C3. WHITE WATER
1927, via Jacumba, El Centro, Niland, and Mecca (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - El Centro	82606	12/1926-3/27	M57 - T59	-19.0695	+0.0183
El Centro - White Water	L-11	1-3/1928	T59 - 1130	+357.9285	+.0096
			Sum =	+344.7420	+0.0279
	Orthometrically corrected height for 1130 =			+344.7699 m	

TABLE C4. WHITE WATER
1928, via San Pedro, Los Angeles, and Colton (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.3656 1/	-0.0022
San Pedro area	82656	5-6/1927	Tidal 8 - G52	+13.9917	.0000
San Pedro - Los Angeles	82583	8/1926	G52 - V32	+76.0058	+.0001
Los Angeles - Ontario	82408	11/1923	V32 - 036	+207.8864	+.0120
Ontario - Riverside	82465	7/1924	036 - V38	-34.7654	+.0060
Riverside - Colton	82464	7-8/1924	V38 - 978	+32.0829	+.0018
Colton - White Water	L-11	1-3/1928	978 - 1130	+46.3255	+.0135
			Sum =	+345.0443	+0.0312
	Orthometrically corrected height for 1130 =			+345.0755 m	

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1928-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1928 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

TABLE C5. WHITE WATER
1931, via San Pedro, Los Angeles, Riverside, San Jacinto, and Banning (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.3610[1/]	-0.0022
San Pedro - Riverside	L-386	1931/1932	Tidal 8 - M38	+239.0345	+.0199
Riverside - White Water	L-7407	1931	M38 - 1130	+102.5681	+.0300
			Sum =	+345.1246	+0.0477
	Orthometrically corrected height for 1130 =			+345.1723 m	

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1931-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1931 to 1931/1932/1933 (see note 1, Table A3 for detailed explantion).

TABLE C6. WHITE WATER
1931, via San Pedro, Los Angeles, and Riverside (4)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.3610[1/]	-0.0022
San Pedro - Riverside	L-386	10/1931-5/32	Tidal 8 - M38	+238.9766	+.0196
Riverside - White Water	L-7407	1931	M38 - 1130	+102.5681	+.0300
			Sum =	+345.0667	+0.0474
	Orthometrically corrected height for 1130 =			+345.1141 m	

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1931-equivalent by allowing for relative movements known to have occurred between San Diego and San Pedro from 1931 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

TABLE C7. WHITE WATER
1931, via Bill Williams River, Freda Junction, Cottonwood Pass, and Indio (5)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - 22Q	Tables A1-A4	--	LMSL - 22Q	+186.7030[1/]	0.0000
22Q - White Water	L-7407	1931	22Q - 1130	+158.1025	+0.0241
			Sum =	+344.8055	+0.0241
	Orthometrically corrected height for 1130 =			+344.8296 m	

Notes:

[1/]This averaged orthometric height is based on the mean value of the 4 first-order heights reconstructed for the Bill Williams River reference mark (Tables A1-A4).

TABLE C8. WHITE WATER
1932, via Oceanside, Santa Ana, Riverside, San Jacinto, and Banning (6)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Santa Ana	L-570	12/1932-1/33	M57 - U36	+39.2492	-0.0016
Santa Ana - Riverside	L-386	10/1931-5/32	U36 - M38	+197.3645	+.0023
Riverside - White Water	L-7407	1931	M38 - 1130	+102.5681	+.0300
			Sum =	+345.0648	+0.0307
	Orthometrically corrected height for 1130 =			+345.0955 m	

TABLE C9. WHITE WATER
1932, via Oceanside, Aguanga, San Jacinto, and Banning (7)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Fallbrook	L-570	12/1932-1/33	M57 - Q63	+179.8614	+0.0013
Fallbrook - Aguanga	82706	7-9/1927	Q63 - A63	+409.2245	+.0413
Aguanga - San Jacinto	L-474	5/1932	A63 - 40L	-129.2666	-.0078
San Jacinto - White Water	L-7407	1931	40L - 1130	-120.7276	-.0095
			Sum =	+344.9747	+0.0253
	Orthometrically corrected height for 1130 =			+345.0000 m	

TABLE C10. WHITE WATER
1968, via San Ysidio, Campo, Julian, Salton City, and Mecca (8)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	L-21529	6-10/1968	M57 - SD241	-2.9503	+.0002
San Ysidro - Julian	L-21532	11/1968-3/70	SD241 - 4219T	+1283.6274	+.1111
Julian - Riv. Co. line	L-21883	11/1968-5/69	4219T - W572	-1323.9629	-.1303
Riv. Co. line - White Water	L-21770	4/1968-6/69	W572 - E71	+424.3510	+.0121
White Water area	L-15875	1-2/1956	E71 - 1130	-41.8877	-.0031
			Sum =	+345.0605	-0.0100
	Orthometrically corrected height for 1130 =			+345.0505 m	

TABLE C11. WHITE WATER
1969, via Miramar, Julian, Salton City, and Mecca (9)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.B830	0.0000
San Diego - Miramar	L-21529	6-10/1968	M57 - H895	+116.4381	+0.0019
Miramar - Santa Ysabel	L-22379	4/1970-3/71	H895 - J62	+787.1405	+.0794
Santa Ysabel - Julian	L-21532	11/1968-3/70	J62 - 4219T	+377.0559	+.0808
Julian - Riv. Co. line	L-21883	11/1968-5/69	4219 - W572	-1323.9629	-.1303
Riv. Co. line - White Water	L-21770	4/1968-6/69	W572 - E71	+424.3510	+.0121
White Water area	L-11	1-3/1928	E71 - 1130	-41.8877	-.0031
			Sum =	+345.0179	+0.0408
	Orthometrically corrected height for 1130 =			+345.0587 m	

TABLE C12. WHITE WATER
1976, via Bill Williams River, Freda Junction, Cottonwood Pass, and Mecca (10)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - 22Q	Tables A1-A4	--	LMSL - 22Q	+186.7030[1/]	0.0000
22Q - 21N	L-24068	5-6/1976	22Q - 21N	+120.4695	+0.0065
21N - 20W	L-24085	9-10/1975	21N - 20W	-7.0468	-.0008
20W - Freda Junc.	L-24077	4-5/1976	20W - 10M	-35.0718	-.0022
Freda Junc. - Cot. P.	L-24080	4-6/1976	10M - J1254	+213.3835	+.0344
Cot. P. - Mecca	L-24071	5-6/1976	J1254 - K572	-536.9184	-.0248
Mecca - White Water	RC0603.1	5-9/1976	K572 - E71	+445.5075	-.0061
White Water area	L-11	1-3/1928	E71 - 1130	-41.8877	-.0031
			Sum =	+345.1388	+0.0039
	Orthometrically corrected height for 1130 =			+345.1427 m	

Notes:

[1/] This averaged orthometric height is based on the mean value of the 4 first-order heights reconstructed for the Bill Williams River reference mark (Tables A1-A4).

TABLE C13. WHITE WATER
1978, via Miramar, Julian, Salton City, and Mecca (9)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Julian	L-24301.18	1-5/1978	M1305 - 4219T	+1151.1644	+.1599
Julian - Mecca	L-24301.19	1-4/1978	4219T - G516r	-1343.6187	-.1293
Mecca - White Water	L-24301.18	1-5/1978	G516r - E71	+444.0020	+.0138
White Water area	L-11	1-3/1928	E71 - 1130	-41.8877	-.0031
			Sum =	+345.0014	+0.0428
	Orthometrically corrected height for 1130 =			+345.0442 m	

TABLE C14. WHITE WATER
1978, Miramar, Julian, El Centro, Niland, and Mecca (11)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - White Water	L-24301.18	1-5/1978	M1305 - E71	+251.5213	+.0920
White Water area	L-11	1-3/1928	E71 - 1130	-41.8877	-.0031
			Sum =	+344.9750	+0.0904
	Orthometrically corrected height for 1130 =			+345.0654 m	

TABLE C15. WHITE WATER
1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca (12)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3222 1/	-0.0022
San Pedro area	L-24301.1	1-5/1978	Tidal 8 - 21-03269	+8.8482	+.0002
San Pedro - Mojave	L-24301.6	1-4/1978	21-03269 - Q49	+835.5896	+.0423
Mojave - Barstow	L-24301.13	1-4/1978	Q49 - GagStn	-203.6716	-.0192
Barstow - Cot. P.	L-24301.23	1-4/1978	GagStn - D723	-101.7026	+.0430
Cot. P. - Mecca	L-24301.28	1-4/1978	D723 - G516r	-599.7839	-.0320
Mecca - White Water	L-24301.18	1-5/1978	G516r - E71	+444.0020	+.0138
White Water area	L-11	1-3/1928	E71 - 1130	-41.8877	-.0031
			Sum =	+344.9548	+0.0428
	Orthometrically corrected height for 1130 =			+344.9976 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1978-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1978. Specifically, relative movement between the San Diego, and San Pedro tide stations has been assessed by comparing linear regressions through the 19-yr mean sea level curves at both tide stations. Linear regressions through the post-1934 San Diego tide station records (when the primary San Diego tide station was located at the Municipal Pier along central San Diego Bay) and through the entire series at San Pedro indicate that sea level at San Pedro has been declining at about 1.56±0.07 mm/yr with respect to the Municipal Pier (Castle and Elliott, 1982, p. 7010, 7016). Interpretation of this decline in sea level as relative uplift at the San Pedro tide station indicates that the 1978 starting height for bench mark Tidal 8, San Pedro (with respect to M57), was approximately 0.0156 m above its 1968/1969 height.

TABLE D1. INDIO
1901, via San Pedro, Los Angeles, and Colton (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.4078[1/]	-0.0022
San Pedro tide station	Castle and others (1986)	--	Tidal 8 - BMA	+3.4248	.0000
San Pedro - Colton	USGS 19th[2/] Ann. Rept.	1897	BMA - 978	+291.3984	+.0170
Colton - White Water	USGS summary book 5816[2/]	2-3/1898	978 - 1130	+46.2117	+.0135
White Water area	USGS summary book 9488[2/]	10-11/1902	1130 - 685T	-135.5074	-.0058
White Water - Indio	USGS summary book 8305 [2/]	2-5/1901	685T - -15T	-213.4212	-.0036
			Sum =	-4.4185	+0.0189
	Orthometrically corrected height for -15T =			-4.3996 m	

Notes:

[1/] The 1931/1932/1933 elevation difference has been corrected to a 1901-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1901 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

[2/] Third-order.

TABLE D2. INDIO
1902, via San Pedro, Los Angeles, and Colton (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.4062[1/]	-0.0022
San Pedro tide station	Castle and others (1986)	--	Tidal 8 - BMA	+3.4248	.0000
San Pedro - Colton	USGS 19th Ann. Rept.[2/]	1897	BMA - 978	+291.3984	+.0170
Colton - Indio	USGS summary book 9488[2/]	10-11/1902	978 - -15T	-302.7329	+.0041
			Sum =	-4.4329	+0.0189
	Orthometrically corrected height for -15T =			-4.4140 m	

Notes:

[1/] The 1931/1932/1933 elevation difference has been corrected to a 1902-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1902 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

[2/] Third-order.

TABLE D3. INDIO
1927, via La Mesa, Santa Ysabel, and Aguanga (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Aguanga	82706	7-9/1927	M57 - A63	+589.1551	+0.0343
Aguanga - Indio	L-8615 1/	4/1939	A63 - -15T	-599.3445	-.0336
			Sum =	-4.3064	+0.0007
	Orthometrically corrected height for -15T =			-4.3057 m	

Notes:

1/ Second-order

TABLE D4. INDIO
1928, via Jacumba, El Centro, Niland, and Mecca (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - El Centro	82606	12/1926-3/27	M57 - T59	-19.0695	+0.0183
El Centro - Indio	L-11	1-3/1928	T59 - -15T	+8.8411	+.0002
			Sum =	-4.3454	+0.0185
	Orthometrically corrected height for -15T =			-4.3269 m	

TABLE D5. INDIO
1930, via Hassayampa, Salome, Blythe, Ogilby, El Centro, Niland, and Mecca (4)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Hassayampa	Tables B2-B4	--	LMSL - 010	+274.5661 1/	0.0000
Hassayampa - Salome	82625	1927	010 - Q12	+297.4445	+0.0014
Salome - Blythe	L-608	1933	Q12 - H133	-489.5563	-.0243
Blythe - Ogilby	L-653.1	3/1933	H133 - S60	-5.5850	+.0064
Ogilby - El Centro	82606	12/1926-3/27	S60 - T59	-90.0433	+.0003
El Centro - Niland - Indio	L-11	1-3/1928	T59 - -15T	+8.8398	+.0002
			Sum =	-4.3342	-0.0160
	Orthometrically corrected height for -15T =			-4.3502 m	

Notes:

1/ This averaged orthometric height is based on the mean value of the 3 first-order heights reconstructed for the Hassayampa reference mark (Tables B2-B4).

TABLE D6. INDIO
1930, via Hassayampa, Salome, Blythe, Ogilby, Niland, and Mecca (5)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Hassayampa	Tables B2-B4	--	LMSL - 010	+274.5661[1/]	0.0000
Hassayampa - Salome	82625	1927	010 - Q12	+297.4445	+0.0014
Salome - Blythe	L-608	1933	Q12 - H133	-489.5563	-.0243
Blythe - Ogilby	L-653.1	3/1933	H133 - S60	-5.5850	+.0064
Ogilby - Niland	L-5584[2/]	3/1935	S60 - R69	-129.4936	-.0022
Niland - Indio	L-11	1-3/1928	R69 - -15T	+48.2654	-.0017
			Sum =	-4.3589	-0.0204
	Orthometrically corrected height for -15T =			-4.3793 m	

Notes:
1/ This averaged orthometric height is based on the mean value of the 3 first-order heights reconstructed for the Hassayampa reference mark (Tables B2-B4).

2/ Second-order

TABLE D7. INDIO
1931, via Bill Williams River, Freda Junction, Cottonwood Pass, and Fargo Junction (6)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - 22Q	Tables A1-A4	--	LMSL - 22Q	+186.7030[1/]	0.0000
22Q - Indio	L-7407	1931	22Q - -15T	-191.0753	+0.0147
			Sum =	-4.3723	+0.0147
	Orthometrically corrected height for -15T =			-4.3576 m	

Notes:

1/ This averaged orthometric height is based on the mean value of the 4 first-order heights reconstructed for the Bill Williams River reference mark (Tables A1-A4).

TABLE D8. INDIO
1932, via San Pedro, Los Angeles, and Riverside (7)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.3594	-.0022
San Pedro - Riverside	L-386	10.1931-5/32	Tidal 8 - M38	+238.9766	+.0196
Riverside - Indio	L-7407	1931	M38 - 15T	-246.6090	+.0206
			Sum =	-4.1088	+0.0380
	Orthometrically corrected height for -15T =			-4.0708 m	

TABLE D9. INDIO
1932, via Oceanside, Aguanga, San Jacinto, Banning, and White Water (B)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Fallbrook	L-570	12/1932-1/33	M57 - Q63	+179.8614	+.0013
Fallbrook - Aguanga	82706	7-9/1927	Q63 - A63	+409.2245	+.0413
Aguanga - San Jacinto	L-474	5/1932	A63 - 40L	-129.2666	-.0078
San Jacinto - Indio	L-7407	1931	40L - -15T	-469.9046	-.0189
			Sum =	-4.2023	+0.0159
	Orthometrically corrected height for -15T =			-4.1864 m	

TABLE D10. INDIO
1939, via Santa Ysabel, Julian, Truckhaven, and Mecca (9)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Santa Ysabel	Tables J2-J9	1938	LMSL - J62	+909.6475 1/	0.0000
Santa Ysabel - Julian	L-8528 2/	2-4/1939	J62 - H308	+376.7574	+0.0817
Julian - Truckhaven	L-8582 2/	3/1939	H308 - V577	-1340.6596	-.1226
Truckhaven - Mecca	L-8583 2/	3/1939	V577 - -189T	-3.1568	-.0005
Mecca - Indio	30th Engineers Survey	1950	-189T - -15T	+53.431	-.0002
			Sum =	-3.9805	-0.0416
	Orthometrically corrected height for -15T =			-4.0221 m	

Notes:

1/ This averaged 1938 orthometric height is based on the mean value of the 8 alternative 1938/1939 heights developed for Santa Ysabel (Tables J2-J9).

2/ Second-order.

TABLE D11. INDIO
1955, via La Mesa, Julian, Truckhaven, and Mecca (10)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Ramona	L-15546	2-3/1955	M57 - A62	+425.9435	+0.0104
Ramona - Truckhaven	L-15872	3-4/1956	A62 - D579	-433.5799	+.0221
Truckhaven - Indio	L-15875	1-3/1956	D579 - -15T	-2.4776	-.0002
			Sum =	-4.2310	+0.0325
	Orthometrically corrected height for -15T =			-4.1985 m	

TABLE D12. INDIO
1955, via Miramar, Julian, Truckhaven, and Mecca (11)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-15549.1	3-4/1955	M57 - U896	+140.6823	+0.0011
Miramar - Poway	L-15543.3[1/]	3/1955	U896 - F321	-11.3796	-.0003
Poway - Woodson	L-15543.5[1/]	3/1955	F321 - C282	+303.0515	+.0135
Woodson - Ramona	L-15546	2-3/1955	C282 - A62	-6.4376	-.0009
Ramona - Truckhaven	L-15872	3-4/1956	A62 - D579	-433.5799	+.0221
Truckhaven - Indio	L-15875	1-2/1956	D579 - -15T	-2.4776	-.0002
			Sum =	-4.2579	+0.0353
	Orthometrically corrected height for -15T =			-4.2226 m	

Notes:

1/ Second-order.

TABLE D13. INDIO
1956, via La Mesa, Santa Ysabel, and Aguanga (4)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Ramona	L-15546	2-3/1955	M57 - A62	+425.9435	+0.0104
Ramona - Santa Ysabel	L-15872	3-4/1956	A62 - J62	+477.6197	+.0672
Santa Ysabel - Aguanga	82706	7-9/1927	J62 - A63	-314.4391	-.0454
Aguanga - Indio	L-15870[1/]	2-4/1956	A63 - -15T	-599.2784	-.0341
			Sum =	-4.2713	-0.0019
	Orthometrically corrected height for -15T =			-4.2732 m	

Notes:

1/ Second-order.

TABLE D14. INDIO
1956, via Miramar, Santa Ysabel, and Aguanga (12)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-15549.1	3-4/1955	M57 - U896	+140.6823	+0.0011
Miramar - Poway	L-15543.3 1/	3/1955	U896 - F321	-11.3796	-.0003
Poway - Woodson	L-15543.5 1/	3/1955	F321 - C282	+303.0515	+.0135
Woodson - Ramona	L-15546	2-3/1955	C282 - A62	-6.4376	-.0009
Ramona - Santa Ysabel	L-15872	3-4/1956	A62 - J62	+477.6197	+.0672
Santa Ysabel - Aguanga	82706	7-9/1927	J62 - A63	-314.4391	-.0454
Aguanga - Indio	L-15870 1/	1-3/1956	A63 - -15T	-599.2784	-.0341
			Sum =	-4.2982	+0.0011
	Orthometrically corrected height for -15T =			-4.2971 m	

Notes:

1/ Second-order.

TABLE D15. INDIO
1968, via San Ysidro, Campo, Julian, Salton City, and Mecca (13)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	L-21529	6-10/1968	M57 - SD241	-2.9503	+0.0002
San Ysidro - Julian	L-21532	11/1968-3/70	SD241 - 4219T	+1283.6274	+.1111
Julian - Riv Co. line	L-21883	11/1968-5/69	4219T - W572	-1323.9629	-.1303
Riv. Co. line - Indio	L-21770	4/1968-6/69	W572 - S70	+26.9724	-.0017
Indio area	L-15875	1-2/1956	S70 - -15T	+6.2230	.0000
			Sum =	-4.2074	-0.0207
	Orthometrically corrected height for -15T =			-4.2281 m	

TABLE D16. INDIO
1969, via Miramar, Santa Ysabel, Julian, Salton City, and Mecca (14)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.883D	0.0000
San Diego - Miramar	L-21529	6-10/1968	M57 - H895	+116.4381	+0.0019
Miramar - Santa Ysabel	L-22379	4/1970-3/71	H895 - J62	+787.1405	+.0794
Santa Ysabel - Julian	L-21532	11/1968-3/70	J62 - 4219T	+377.0559	+.0808
Julian - Riv. Co. line	L-21883	11/1968-5/69	4219T - W572	-1323.9629	-.13D3
Riv. Co. line - Indio	L-21770	4/1968-6/69	W572 - S70	+26.9724	-.0017
Indio area	L-15875	1-2/1965	S70 - -15T	+6.2230	.0000
			Sum =	-4.2500	+0.0301
	Orthometrically corrected height for -15T =			-4.2199 m	

TABLE D17. INDIO
1976, via Bill Williams River, Freda Junction, Cottonwood Pass, and Mecca (15)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - 22Q	Tables A1-A4		LMSL - 22Q	+186.7030[1/]	0.0000
22Q - 21N	L-24068	5-6/1976	22Q - 21N	+120.4695	+0.0065
21N - 20W	L-24085	9-10/1975	21N - 20W	-7.0468	-.0008
20W - Freda Junc.	L-24077	4-5/1976	20W - 10M	-35.0718	-.0022
Freda Junc. - Cot. P.	L-24080	4-6/1976	10M - J1254	+213.3835	+.0344
Cot. P. - Mecca	L-24071	5-6/1976	J1254 - K572	-536.9184	-.0248
Mecca - Indio	RC0603.1	5-9/1976	K572 - S70	+48.1354	-.0004
Indio area	L-15875	1-2/1956	S70 - -15T	+6.2330	.0000
			Sum =	-4.1226	+0.0127
	Orthometrically corrected height for -15T =			-4.1099 m	

Notes:

1/ This averaged orthometric height is based on the mean value of the 4 first-order heights reconstructed for the Bill Williams River reference mark (Tables A1-A4).

TABLE D18. INDIO
1978, via Miramar, Julian, Ocotillo, El Centro, Niland, and Mecca (16)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Indio	L-24301.18	1-5/1978	M1305 - S70	145.7985	+.0779
Indio area	L-15875	1-2/1956	S70 - -15T	+6.2230	.0000
			Sum =	-4.2341	+0.0794
	Orthometrically corrected height for -15T =			-4.1547 m	

TABLE D19. INDIO
1978, via Miramar, Santa Ysabel, Julian, Salton City, and Mecca (14)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Julian	L-24301.18	1-5/1978	M13D5 - 4219T	+1151.1644	+.1599
Julian - Miramar	L-24301.19	1-4/1978	4219T - G516r	-1343.6187	-.1293
Mecca - Indio	L-24301.18	1-5/1978	G516r - S70	+46.6822	-.0003
Indio area	L-15875	1-2/1956	S70 - -15T	+6.2230	.0000
			Sum =	-4.2077	+0.0318
	Orthometrically corrected height for -15T =			-4.1759 m	

TABLE D20. INDIO
1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca (17)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3222[1/]	-0.0022
San Pedro area	L-24301.1	1-5/1978	Tidal 8 - 21-03269	+8.8482	+.0002
San Pedro - Mojave	L-24301.6	1-4/1978	21-03269 - Q49	+835.5896	+.0423
Mojave - Barstow	L-24301.3	1-4/1978	Q49 - GagStn	-203.6716	-.0192
Barstow - Cot. P.	L-24301.23	1-4/1978	GagStn - D723	-101.7026	+.0430
Cot. P. - Mecca	L-24301.28	1-4/1978	D723 - G516r	-599.7839	-.0320
Mecca - Indio	L-24301.18	1-5/1978	G516r - S70	+46.6822	-.0003
Indio area	L-15875	1-2/1956	S70 - -15T	+6.2230	.0000
			Sum =	-4.2543	+0.0318
	Drthometrically corrected height for -15T =			-4.2225 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1978-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1978 (see note 1, Table C15 for detailed explanation).

TABLE E1. MECCA
1901, via San Pedro, Los Angeles, and Colton (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.4078 1/	-0.0022
San Pedro tide station	Castle and others (1986)	--	Tidal 8 - BMA	+3.4248	.0000
San Pedro - Colton	USGS 19th Ann. Rept. 2/	1897	BMA - 978	+291.3984	+.0170
Colton - White Water	USGS summary book 5816 2/	2-3/1898	978 - 1130	+46.2117	+.0135
White Water area	USGS summary book 9488 2/	10-11/1902	1130 - 685T	-135.5074	-.0058
White Water - Mecca	USGS summary book 8305 2/	2-5/1901	685T - -189T	-266.5490	-.0036
			Sum =	-57.5463	+0.0189

Orthometrically corrected height for -189T = -57.5274 m

from Table 4, G516 = -57.2952 m
K572 = -58.4293 m

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1901-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1901 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

2/ Third-order.

TABLE E2. MECCA
1902, via San Pedro, Los Angeles, and Colton (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.4062 1/	-0.0022
San Pedro tide station	Castle and others (1986)	--	Tidal 8 - BMA	+3.4248	.0000
San Pedro - Colton	USGS 19th Ann. Rept. 2/	1897	BMA - 978	+291.3984	+.0170
Colton - Mecca	USGS summary book 9488 2/	10-11/1902	978 - -189T	-355.8278	+.0043
			Sum =	-57.5278	+0.0191
	Orthometrically corrected height for -189T =			-57.5087 m	
		from Table 4,	G516 =	-57.2765 m	
			K572 =	-58.4106 m	

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1902-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1902 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

2/ Third-order.

TABLE E3. MECCA
1927, via Jacumba, El Centro, and Niland (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - El Centro	82606	12/1926-3/27	M57 - T59	-19.0695	-0.0183
El Centro - Mecca	L-11	1-3/1928	T59 - -189T	-44.5319	+.0004
			Sum =	-57.7184	+0.0187
	Orthometrically corrected height for -189T =			-57.6997 m	
		from Table 4,	G516 =	-57.4675 m	
			K572 =	-58.6016 m	

TABLE E4. MECCA
1928, via La Mesa, Santa Ysabel, Aguanga, and Indio (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Aguanga	82706	7-9/1927	M57 - A63	+589.1551	+0.0343
Aguanga - Indio	L-8615[1/]	4/1939	A63 - -15T	-599.3445	-.0336
Indio - Mecca	L-11	1-3/1928	-15T - -189T	-53.3730	+.0002
			Sum =	-57.6794	+0.0009
	Orthometrically corrected height for -189T =			-57.6785 m	
		from Table 4,	G516 = K572 =	-57.4463 m -58.5804 m	

Notes:

1/ Second-order.

TABLE E5. MECCA
1930, via Hassayampa, Salome, Blythe, Ogilby, El Centro, and Niland (4)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Hassayampa	Tables B2-B4	--	LMSL - 010	+274.5661	0.0000
Hassayampa - Salome	82625	1927	010 - Q12	+297.4445	+0.0014
Salome - Blythe	L-608	1933	Q12 - H133	-489.5563	-.0243
Blythe - Ogilby	L-653.1	3/1933	H133 - S60	-5.5850	+.0064
Ogilby - El Centro	82606	12/1926 - 3/27	S60 - T59	-90.0433	+.0003
El Centro - Niland - Mecca	L-11	1-3/1928	T59 - -189T	-44.5332	+.0004
			Sum =	-57.7072	-0.0158
	Orthometrically corrected height for -189T =			-57.7230 m	
		from Table 4,	G516 = K572 =	-57.4908 m -58.6249 m	

Notes:

1/ This averaged orthometric height is based on the mean value of the 3 first-order heights reconstructed for the Hassayampa reference mark (Tables B2-B4).

TABLE E6. MECCA
1930, via Hassayampa, Salome, Blythe, Ogilby, and Niland (5)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Hassayampa	Tables B2-B4	--	LMSL - 010	+274.5661[1]	0.0000
Hassayampa - Salome	82625	1927	010 - Q12	+297.4445	+0.0014
Salome - Blythe	L-608	1933	Q12 - H133	-489.5563	-.0243
Blythe - Ogilby	L-653.1	3/1933	H133 - S60	-5.5850	+.0064
Ogilby - Niland	L-5584[2]	3/1935	S60 - R69	-129.4936	-.0022
Niland - Mecca	L-11	1-3/1928	R69 - -189T	-5.1076	-.0015
			Sum =	-57.7319	-0.0202
	Orthometrically corrected height for -189T =			-57.7521 m	
		from Table 4,	G516 =	-57.5199 m	
			K572 =	-58.6560 m	

Notes:

1/ This averaged orthometric height is based on the mean value of the 3 first-order heights reconstructed for the Hassayampa reference mark (Tables B2-B4).

2/ Second-order.

TABLE E7. MECCA
1931, via Bill Williams River, Freda Junction, and Cottonwood Pass (6)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - 22Q	Tables A1-A4	--	LMSL - 22Q	+186.7030[1]	0.0000
22Q - Indio	L-7407	1931	22Q - -15T	-191.0753	+0.0147
Indio - Mecca	L-11	1-2/1928	-15T - -189T	-53.3730	+.0004
			Sum =	-57.7453	+0.0151
	Orthometrically corrected height for -189T =			-57.7302 m	
		from Table 4,	G516 =	-57.4980 m	
			K572 =	-58.6321 m	

Notes:

1/ This averaged orthometric height is based on the mean value of the 4 first-order heights reconstructed for the Bill Williams River reference mark (Tables A1-A4).

TABLE E8. MECCA
1939, via Santa Ysabel, Julian, and Truckhaven (7)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Santa Ysabel	Tables J2-J9	1938	LMSL - J62	+909.6475[1]	0.0000
Santa Ysabel - Julian	L-8528[2]	2-4/1939	J62 - H308	+376.7574	+0.0817
Julian - Truckhaven	L-8582[2]	3/1939	H308 - V577	-1340.6596	-.1226
Truckhaven - Mecca	L-8583[2]	3/1939	V577 - -189T	-3.1568	-.0005
			Sum =	-57.4453	-0.0414
	Orthometrically corrected height for -189T =			-57.4529 m	
		from Table 4,	G516 =	-57.2207 m	
			K572 =	-58.3548 m	

Notes:

1/ This averaged 1938 orthometric height is based on the mean value of the 8 alternative heights developed for Santa Ysabel (Tables J2-J9).

2/ Second-order.

TABLE E9. MECCA
1955, via La Mesa, Santa Ysabel, Julian, and Truckhaven (8)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Ramona	L-15546	2-3/1955	M57 - A62	+425.9435	+0.0104
Ramona - Truckhaven	L-15872	3-4/1956	A62 - D579	-433.5799	+.0221
Truckhaven - Mecca	L-15875	1-3/1956	D579 - -189T	-56.0402	.0000
			Sum =	-57.7936	+0.0325
	Orthometrically corrected height for -189T =			-57.7611 m	
		from Table 4,	G516 =	-57.5289 m	
			K572 =	-58.5724 m	

TABLE E10. MECCA
1955, via Miramar, Santa Ysabel, Julian, and Truckhaven (9)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-15549.1	3-4/1955	M57 - U896	+140.6823	+0.0011
Miramar - Poway	L-15543.3[1/]	3/1955	U896 - F321	-11.3796	-.0003
Poway - Woodson	L-15543.5[1/]	3/1955	F321 - C282	+303.0515	+.0135
Woodson - Ramona	L-15546	2-3/1955	C282 - A62	-6.4376	-.0009
Ramona - Truckhaven	L-15872	3-4/1956	A62 - D579	-433.5799	+.0221
Truckhaven - Mecca	L-15875	1-3/1956	D579 - -189T	-56.0402	.0000
			Sum =	-57.8205	+0.0355
	Orthometrically corrected height for -189T =			-57.7850 m	
		from Table 4,	G516 =	-57.5528 m	
			K572 =	-58.5963 m	

Notes:

1/ Second-order.

TABLE E11. MECCA
1956, via La Mesa, Santa Ysabel, Aguanga, and Indio (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Ramona	L-15546	2-3/1955	M57 - A62	+425.9435	+0.0104
Ramona - Santa Ysabel	L-15872	3-4/1956	A62 - J62	+477.6197	+.0672
Santa Ysabel - Aguanga	82706	7-9/1927	J62 - A63	-314.4391	-.0454
Aguanga - Indio	L-15870[1/]	2-4/1956	A63 - -15T	-599.2784	-.0341
Indio - Mecca	L-15875	1-3/1956	-15T - -189T	-53.5626	+.0002
			Sum =	-57.8339	-0.0017
	Orthometrically corrected height for -189T =			-57.8356 m	
		from Table 4,	G516 =	-57.6034 m	
			K572 =	-58.6469 m	

Notes:

1/ Second-order.

TABLE E12. MECCA
1956, via Miramar, Santa Ysabel, Aguanga, and Indio (10)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-15549.1	3-4/1955	M57 - U896	+140.6823	+0.0011
Miramar - Poway	L-15543.3 1/	3/1955	U896 - F321	-11.3796	-.0003
Poway - Woodson	L-15543.5 1/	3/1955	F321 - C282	+303.0515	+.0135
Woodson - Ramona	L-15546	2-3/1955	C282 - A62	-6.4376	-.0009
Ramona - Santa Ysabel	L-15872	3-4/1956	A62 - J62	+477.6197	+.0672
Santa Ysabel - Aguanga	82706	7-9/1927	J62 - A63	-314.4391	-.0454
Aguanga - Indio	L-15870 1/	1-3/1956	A63 - -15T	-599.2784	-.0341
Indio - Mecca	L-15875	1-3/1956	-15T - -189T	-53.5626	+.0002
			Sum =	-57.8608	+0.0112
	Orthometrically corrected height for -189T =			-57.8496 m	
		from Table 4,	G516 =	-57.6174 m	
			K572 =	-58.6609 m	

Notes:

1/ Second-order.

TABLE E13. MECCA
1968, via San Ysidro, Campo, Julian, and Salton City (11)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	L-21529	6-10/1968	M57 - SD241	-2.9503	+0.0002
San Ysidro - Julian	L-21532	11/1968-3/70	SD241 - 4219T	+1283.6274	+.1111
Julian - Riv. Co. line	L-21883	11/1968-5/69	4219T - W572	-1323.9629	-.1303
Riv. Co. line - Mecca	L-21770	4/1968-6/69	W572 - G516	-20.0772	-.0013
			Sum =	-57.4800	-0.0203
	Orthometrically corrected height for G516 =			-57.5003 m	
		from Table 4,	K572 =	-58.5733 m	

TABLE E14. MECCA
1969, via Miramar, Santa Ysabel, Julian, and Salton City (12)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-21529	6-10/1968	M57 - H895	+116.4381	+0.0019
Miramar - Santa Ysabel	L-22379	4/1970-3/71	H895 - J62	+787.1405	+.0794
Santa Ysabel - Julian	L-21532	11/1968-3/70	J62 - 4219T	+377.0559	+.0808
Julian - Riv. Co. line	L-21883	11/1968-5/69	4219T - W572	-1323.9629	-.1303
Riv. co. line - Mecca	L-21770	4/1968-6/69	W572 - G516	-20.0772	-.0013
			Sum =	-57.5226	+0.0305
	Orthometrically corrected height for G516 =			-57.4921 m	
		from Table 4,	K572 =	-58.5651 m	

TABLE E15. MECCA
1974, via San Pedro, Los Angles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, and Cottonwood Pass (13)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3284 1/	-0.0022
San Pedro area	L-23644	1-2/1974	Tidal 8 - 21-03690	+9.7053	+.0001
San Pedro - Los Angeles	L-23611	1-3/1974	21-03690 - 338	+90.3218	-.0001
Los Angeles - San Fernando	L-23614	7-11/1973	338 - 04-00855	+276.0888	+.0162
San Fernando - Saugus	L-23691	3-7/1973	04-00855 - 1171	-22.8927	-.0013
Saugus - Palmdale	L-23679	11/1972-3/73	1171 - Loft	+550.5059	+.0524
Palmdale - LA Co. line	L-23671	10/1973-2/74	Loft - M487	-203.5111	-.0292
LA Co. line - Rosamond	L-23685	2-10/1974	M487 - E1147	+34.2195	+.0050
Rosamond - Barstow	L-23208	11/1973-2/74	E1147 - F43	-95.8787	-.0177
Barstow - Amboy	L-23227	2-3/1974	F43 - T1250	-456.3090	-.0224
Amboy - Mecca	L-23315	3-5/1974	T1250 - K572	-244.2525	+.0347
			Sum =	-58.4481	+0.0427
	Orthometrically corrected height for K572 =			-58.4054 m	
		from Table 4,	G516 =	-57.3734 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1974-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1974 (see note 1, Table C15 for detailed explanation).

TABLE E16. MECCA
1976, via Bill Williams River, Freda Junction, and Cottonwood Pass (14)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - 22Q	Tables A1-A4	--	LMSL - 22Q	+186.7030[1/]	0.0000
22Q - 21N	L-24068	5-6/1976	22Q - 21N	+120.4695	+0.0065
21N - 20W	L-24085	9-10/1975	21N - 20W	-7.0468	-.0008
20W - Freda Junc.	L-24077	4-5/1976	20W - 10M	-35.0718	-.0022
Freda Junc. - Cot. P.	L-24080	4-6/1976	10M - J1254	+213.3835	+.0344
Cot. P. - Mecca	L-24071	5-6/1976	J1254 - K572	-536.9184	-.0248
			Sum =	-58.4810	+0.0131
	Orthometrically corrected height for K572 =			-58.4679 m	
		from Table 4,	G516 =	-57.4411 m	

Notes:

1/ This averaged orthometric height is based on the mean value of the 4 first-order heights reconstructed for the Bill Williams reference mark (Tables A1-A4).

TABLE E17. MECCA
1978, via Miramar, Santa Ysabel, Julian, and Salton City (12)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Julian	L-24301.18	1-5/1978	M1305 - 4219T	+1151.1644	+.1599
Julian - Mecca	L-24301.19	1-4/1978	4219T - K572	-1345.0885	-.1293
			Sum =	-58.5827	+0.0321
	Orthometrically corrected height for K572 =			-58.5506 m	
		from Table 4,	G516 =	-57.4725 m	

TABLE E18. MECCA
1978, via Miramar, Julian, Octollo, El Centro, and Niland (15)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Mecca	L-24301.18	1-5/1978	M1305 - G516r	-192.4807	+.0782
Mecca area	L-24301.19	1-4/1978	G516r - K572	-1.4698	.0000
			Sum =	-58.6091	+0.0797
	Orthometrically corrected height for K572 =			-58.5294 m	
		from Table 4,	G516 =	-57.4513 m	

TABLE E19. MECCA
1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, and Cottonwood Pass (13)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3222 1/	-0.0022
San Pedro area	L-24301.1	1-5/1978	Tidal 8 - 21-03269	+8.8482	+.0002
San Pedro - Mojave	L-24301.6	1-4/1978	21-03269 - Q49	+835.5896	+.0423
Mojave - Barstow	L-24301.13	1-4/1978	Q49 - GagStn	-203.6716	-.0192
Barstow - Cot. P.	L-24301.23	1-4/1978	GagStn - D723	-101.7026	+.0430
Cot. P. - Mecca	L-24301.28	1-4/1978	D723 - G516r	-599.7839	-.0320
Mecca area	L-24301.19	1-4/1978	G516r - K572	-1.4698	.0000
			Sum =	-58.6293	+0.0321
	Orthometrically corrected height for K572 =			-58.5972 m	
		from Table 4,	G516 =	-57.5191 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1978-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1978 (see note 1, Table C15 for detailed explanation).

TABLE F1. SALTON CITY
1939, via Santa Ysabel, Julian, and Truckhaven (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Santa Ysabel	Tables J2-J9	1938	LMSL - J62	+909.6475[1]	0.0000
Santa Ysabel - Julian	L-8528[2]	2-4/1939	J62 - H308	+376.7574	+0.0817
Julian - Truckhaven	L-8582[2]	3/1939	H308 - V577	-1340.6596	-.1226
Truckhaven - Salton City	L-8583[2]	3/1939	V577 - G577	+32.8758	.0000
			Sum =	-21.3789	-0.0409
	Orthometrically corrected height for G577 =			-21.4198 m	

Notes:

1/ This averaged 1938 orthometric height is based on the mean value of the 8 alternative 1938/1939 heights developed for Santa Ysabel (Tables J2-J9).

2/ Second-order.

TABLE F2. SALTON CITY
1955, via La Mesa, Ramona, Julian, and Truckhaven (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Ramona	L-15446	2-3/1955	M57 - A62	+425.9435	+0.0104
Ramona - Truckhaven	L-15872	3-4/1956	A62 - D579	-433.5799	+.0221
Truckhaven - Salton City	L-15875	1-3/1956	D579 - G577	-19.8500	+.0006
			Sum =	-21.6034	+0.0331
	Orthometrically corrected height for G577 =			-21.5703 m	

TABLE F3. SALTON CITY
1955, via Miramar, Ramona, Julian, and Truckhaven (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-15549.1	3-4/1955	M57 - U896	+140.6823	+0.0011
Miramar - Poway	L-15543.3[1/]	3/1955	U896 - F321	-11.3796	-.0003
Poway - Woodson	L-15543.5[1/]	3/1955	F321 - C282	+303.0515	+.0135
Woodson - Ramona	L-15546	2-3/1955	C282 - A62	-6.4376	-.0009
Ramona - Truckhaven	L-15872	3-4/1956	A62 - D579	-433.5799	+.0221
Truckhaven - Salton City	L-15875	1-3/1956	D579 - G577	-19.8500	+.0006
			Sum =	-21.6303	+0.0361
	Orthometrically corrected height for G577 =			-21.5942 m	

Notes:

1/ Second-order.

TABLE F4. SALTON CITY
1956, via Miramar, Santa Ysabel, Aguanga, Indio, and Mecca (4)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-15549.1	3-4/1955	M57 - U896	+140.6823	+0.0011
Miramar - Poway	L-15543.3[1/]	3/1955	U896 - F321	-11.3796	-.0003
Poway - Woodson	L-15543.5[1/]	3/1955	F321 - C282	+303.0515	+.0135
Woodson - Ramona	L-15546	2-3/1955	C282 - A62	-6.4376	-.0009
Ramona - Santa Ysabel	L-15872	3-4/1956	A62 - J62	+477.6197	+.0672
Santa Ysabel - Aguanga	82706	7-9/1927	J62 - A63	-314.4391	-.0454
Aguanga - Indio	L-15870[1/]	2-4/1956	A63 - -15T	-599.2784	-.0341
Indio - Salton City	L-15875	1-3/1956	-15T - G577	-17.3724	+.0008
			Sum =	-21.6706	+0.0019
	Orthometrically corrected height for G577 =			-21.6687 m	

Notes:

1/ Second-order.

TABLE F5. SALTON CITY
1968, via Campo, Julian, and Borrego (5)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	L-21529	6-10/1968	M57 - SD241	-2.9503	+0.0002
San Ysidro - Julian	L-21532	11/1968-3/70	SD241 - 4219T	+1283.6274	+.1111
Julian - Salton City	L-21883	11/1968-5/69	4219T - G577	-1308.1659	-.1312
			Sum =	-21.6058	-0.0199
	Orthometrically corrected height for G577 =			-21.6257 m	

TABLE F6. SALTON CITY
1969, via Miramar, Julian, and Borrego (6)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-21529	6-10/1968	M57 - H895	+116.4381	+0.0019
Miramar - Santa Ysabel	L-22379	4/1970-3/71	H895 - J62	+787.1405	+.0794
Santa Ysabel - Julian	L-21532	11/1968-3/70	J62 - 4219T	+377.0559	+.0808
Julian - Salton City	L-21883	11/1968-5/69	4219T - G577	-1308.1659	-.1312
			Sum =	-21.6484	+0.0309
	Orthometrically corrected height for G577 =			-21.6175 m	

TABLE F7. SALTON CITY
1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca (7)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3284[1/]	-0.0022
San Pedro area	L-23644	1-2/1974	Tidal 8 - 21-03690	+9.7053	+.0001
San Pedro - Los Angeles	L-23611	1-3/1974	21-03690 - 338	+90.3218	-.0001
Los Angeles - San Fernando	L-23614	7-11/1973	338 - 04-00855	+276.0888	+.0162
San Fernando - Saugus	L-23691	3-7/1973	04-00855 - 1171	-22.8927	-.0013
Saugus - Palmdale	L-23679	11/1972-3/73	1171 - Loft	+550.5059	+.0524
Palmdale - LA Co. line	L-23671	10/1973-2/74	Loft - M487	-203.5111	-.0292
LA Co. line - Rosamond	L-23685	2-10/1974	M487 - E1147	+34.2195	+.0050
Rosamond - Barstow	L-23208	11/1973-2/74	E1147 - F43	-95.8787	-.0177
Barstow - Amboy	L-23227	2-3/1974	F43 - T1250	-456.3090	-.0224
Amboy - Mecca	L-23315	3-5/1974	T1250 - K572	-244.2525	+.0347
Mecca - Imp. Co. line	L-23501	5-9/1974	K572 - W572	+21.1712	+.0014
Imp. Co. line - Salton City	L-23349	3/1974	W572 - G577	+15.7785	-.0009
			Sum =	-21.4984	+0.0432
	Orthometrically corrected height for G577 =			-21.4552 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1974-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1978 (see note 1, Table C15 for detailed explanation).

TABLE F8. SALTON CITY
1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, Mecca, Niland, Rockwood, and Truckhaven (8)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3284[1/]	-0.0022
San Pedro area	L-23644	1-2/1974	Tidal 8 - 21-03690	+9.7053	+.0001
San Pedro - Los Angeles	L-23611	1-3/1974	21-03690 - 338	+90.3218	-.0001
Los Angeles - San Fernando	L-23614	7-11/1973	338 - 04-00855	+276.0888	+.0162
San Fernando - Saugus	L-23691	3-7/1973	04-00855 - 1171	-22.8927	-.0013
Saugus - Palmdale	L-23679	11/1972-3/73	1171 - Loft	+550.5059	+.0524
Palmdale - LA Co. line	L-23671	10/1973-2/74	Loft - M487	-203.5111	-.0292
LA Co. line - Rosamond	L-23685	2-10/1974	M487 - E1147	+34.2195	+.0050
Rosamond - Barstow	L-23208	11/1973-2/74	E1147 - F43	-95.8787	-.0177
Barstow - Amboy	L-23227	2-3/1974	F43 - T1250	-456.3090	-.0224
Amboy - Frink	L-23315	3-5/1974	T1250 - V614	-244.1347	+.0371
Frink - Rockwood	L-23243	12/1973-2/74	V614 - F611r	+10.8487	-.0004
Rockwood - Westmorland	L-23343	12/1973-1/74	F611r - M578	-4.0558	.0000
Westmorland area	L-23361	12/1973-4/74	M578 - H578	+3.8867	.0000
Westmorland area	L-23712	2/1975	H578 - F578r	-0.7132	.0000
Westmorland - Salton City	L-23361	12/1973-4/74	F578r - G577	+26.9608	-.0005
			Sum =	-21.4031	+0.0370
	Orthometrically corrected height for G577 =			-21.3661 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1974-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1974 (see note 1, Table C15 for detailed explanation).

TABLE F9. SALTON CITY
1978, via Miramar, Julian, and Borrego (6)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Julian	L-24301.18	1-5/1978	M1305 - 4219T	+1151.1644	+.1599
Julian - Salton City	L-24301.19	1-4/1978	4219T - G577	-1308.1981	-.1287
			Sum =	-21.6923	+0.0327
	Orthometrically corrected height for G577 =			-21.6596 m	

TABLE F10. SALTON CITY
1978, via Miramar, Julian, El Centro, Niland, and Mecca (9)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Mecca	L-24301.18	1-5/1978	M1305 - G516r	-192.4807	+.0782
Mecca - Salton City	L-24301.19	1-4/1978	G516r - G577	+35.4206	+.0006
			Sum =	-21.7187	+0.0803
	Orthometrically corrected height for G577 =			-21.6384 m	

TABLE G1. NILAND
1927, via Jacumba and El Centro (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - El Centro	82606	12/1926-3/27	M57 - T59	-19.0695	+0.0183
El Centro - Niland	L-11	1-3/1928	T59 - R69	-39.4256	+.0019
			Sum =	-52.6121	+0.0202
	Orthometrically corrected height for R69 =			-52.5919 m	

TABLE G2. NILAND
1939, via Santa Ysabel, Truckhaven, and Rockwood (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Santa Ysabel	Tables J2-J9	1938	LMSL - J62	+909.6475[1]	0.0000
Santa Ysabel - Julian	L-8528[2]	2-4/1939	J62 - H308	+376.7574	+0.0817
Julian - Truckhaven	L-8582[2]	3/1939	H308 - V577	-1340.6596	-.1226
Truckhaven - Rockwood	L-8583[2]	3/1939	V577 - M69	+5.8979	+.0004
Rockwood - Niland	L-222	2-3/1931	M69 - R69	-3.8291	+.0005
			Sum =	-52.1859	-0.0400
	Orthometrically corrected height for R69 =			-52.2259 m	

Notes:

1/ This averaged 1938 orthometric height is based on the mean value of the 8 alternative 1938/1939 heights developed for Santa Ysabel (Tables J2-J9).

2/ Second-order.

TABLE G3. NILAND
1955, via Miramar, Ramona, Julian, Truckhaven, and Rockwood (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-15549.1	3-4/1955	M57 - U896	+140.6823	+0.0011
Miramar - Poway	L-15543.3 1/	3/1955	U896 - F321	-11.3796	-.0003
Poway - Woodson	L-15543.5 1/	3/1955	F321 - C282	+303.0515	+.0135
Woodson - Ramona	L-15546	2-3/1955	C282 - A62	-6.4376	-.0009
Ramona - Truckhaven	L-15872	3-4/1956	A62 - D579	-433.5799	+.0221
Truckhaven area	L-15875	1-3/1956	D579 - V577	-52.7125	+.0005
Truckhaven - Rockwood	L-8583 1/	3/1939	V577 - M69	+5.8979	+.0004
Rockwood - Niland	L-9173	5-6/1941	M69 - R69	-3.8221	+.0005
			Sum =	-52.4170	+0.0369
	Orthometrically corrected height for R69 =			-52.3801 m	

Notes:

1/ Second order

TABLE G4. NILAND
1956, via La Mesa, Ramona, Julian, Truckhaven, and Rockwood (4)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Ramona	L-15546	2-3/1955	M57 - A62	+425.9435	+0.0104
Ramona - Truckhaven	L-15872	3-4/1956	A62 - D579	-433.5799	+.0221
Truckhaven area	L-15875	1-3/1956	D579 - V577	-52.7125	+.0005
Truckhaven - Rockwood	L-8583 1/	3/1939	V577 - M69	+5.8979	+.0004
Rockwood - Niland	L-9173	5-6/1941	M69 - R69	-3.8221	+.0005
			Sum =	-52.3901	+0.0339
	Orthometrically corrected height for R69 =			-52.3562 m	

Notes:

1/ Second-order.

TABLE G5. NILAND
1972, via Hassayampa, Salome, Blythe, Palo Verde, Ogilby, and El Centro (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Hassayampa	Tables B2-B4	--	LMSL - 010	+274.5661[1/]	0.0000
Hassayampa - Burning Well	L-24555.3	3-4/1981	010 - R476	+101.4902[2/]	+0.0010
Burning Well - Salome	L-24562.3	12/1981-1/82	R476 - A478	+184.6105[2/]	+0.0045
Salome - Palo Verde	L-24562.2	11-12/1981	A478 - S1231	-340.2187[2/]	-.0190
Palo Verde - Ogilby	L-22668	2-4/1972	S1231 - L133	-85.3218	-.0030
Ogilby - El Centro	L-22603	10/1971-1/72	L133 - W89	-147.4277	+.0003
El Centro - Niland	L-22606	1-2/1972	W89 - R69	-40.1651	+.0019
			Sum =	-52.4665	-0.0143
	Orthometrically corrected height for R69 =			-52.4808 m	

Notes:

1/ The averaged orthometric height difference is based on the mean value of the 3 first-order heights reconstructed for the Hassayampa reference mark (Tables B2-B4).

2/ These 1981 elevation differences are assumed to be 1972-equivalents. This interpretation indicates that Palo Verde sustained net uplift of some 0.12 m between 1933 and 1972 with respect to an invariant reference point such as San Diego (see text for details). If Palo Verde was assumed to have remained fixed between 1933 and 1972, an alternative open circle 1972 height would plot 0.122 m lower (see fig. 16).

TABLE G6. NILAND
1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca (6)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3284[1/]	-0.0022
San Pedro area	L-23644	1-2/1974	Tidal 8 - 21-03690	+9.7053	+.0001
San Pedro - Los Angeles	L-23611	1-3/1974	21-03690 - 338	+90.3218	-.0001
Los Angeles - San Fernando	L-23614	7-11/1973	338 - 04-00855	+276.0888	+.0162
San Fernando - Saugus	L-23691	3-7/1973	04-00855 - 1171	-22.8927	-.0013
Saugus - Palmdale	L-23679	11/1972-3/73	1171 - Loft	+550.5059	+.0524
Palmdale - LA Co. line	L-23671	10/1973-2/74	Loft - M487	-203.5111	-.0292
LA Co. line - Rosamond	L-23685	2-10/1974	M487 - E1147	+34.2195	+.0050
Rosamond - Barstow	L-23208	11/1973-2/74	E1147 - F43	-95.8787	-.0177
Barstow - Amboy	L-23227	2-3/1974	F43 - T1250	-456.3090	-.0224
Amboy - Frink	L-23315	3-5/1974	T1250 - V614	-244.1347	+.0347
Frink - Niland	L-23243	12/1973-2/74	V614 - R69	+6.1104	.0000
			Sum =	-52.2199	+0.0355
	Orthometrically corrected height for R69 =			-52.1844 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1974-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1974 (see note 1, Table C15 for detailed explanation).

TABLE G7. NILAND
1976, Bill Williams River, Freda Junction, Cottonwood Pass, and Mecca (7)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - 22Q	Tables A1-A4	--	LMSL - 22Q	+186.7030[1/]	0.0000
22Q - 21N	L-24068	5-6/1976	22Q - 21N	+120.4695	+0.0065
21N - 20 W	L-24085	9-10/1975	21N - 20W	-7.0468	-.0008
20W - Freda Junc.	L-24077	4-5/1976	20W - 10M	-35.0718	-.0022
Freda Junc. - Cot. P.	L-24080	4-6/1976	10M - J1254	+213.3835	+.0344
Cot. P. - Frink	L-24071	5-6/1976	J1254 - V614	-536.8244	-.0234
Frink - Niland	L-24130.1	11/1976-1/77	V614 - R69	+6.1162	.0000
			Sum =	-52.2708	+0.0145
	Orthometrically corrected height for R69 =			-52.2563 m	

Notes:

[1/]This averaged orthometric height is based on the mean value of the 4 first-order heights reconstructed for the Bill Williams River reference mark (Tables A1-A4).

TABLE G8. NILAND
1978, via Miramar, Julian, Ocotillo, and El Centro (8)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Niland	L-24301.18	1-5/1978	M1305 - R69	-187.8140	+.0795
			Sum =	-52.4726	+0.0810
	Orthometrically corrected height for R69 =			-52.3916 m	

TABLE G9. NILAND
1978, via Miramar, Julian, Salton City, and Mecca (9)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Julian	L-24301.18	1-5/1978	M1305 - 4219T	+1151.1644	+.1599
Julian - Mecca	L-24301.19	1-4/1978	4219T - G516r	-1343.6187	-.1293
Mecca - Niland	L-24301.18	1-5/1978	G516r - R69	+4.6667	+.0013
			Sum =	-52.4462	+0.0334
	Orthometrically corrected height for R69 =			-52.4128 m	

TABLE G10. NILAND
1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, and Mecca (6)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3222 1/	-0.0022
San Pedro area	L-24301.1	1-5/1978	Tidal 8 - 21-03269	+8.8482	+.0002
San Pedro - Mojave	L-24301.6	1-4/1978	21-03269 - Q49	+835.5896	+.0423
Mojave - Barstow	L-24301.13	1-4/1978	Q49 - GagStn	-203.6716	-.0192
Barstow - Cot. P.	L-24301.23	1-4/1978	GagStn - D723	-101.7026	+.0430
Cot. P. - Mecca	L-24301.28	1-4/1978	D723 - G516r	-599.7839	-.0320
Mecca - Niland	L-24301.18	1-5/1978	G516r - R69	+4.6667	+.0013
			Sum =	-52.4928	+0.0334
	Orthometrically corrected height for R69 =			-52.4594 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1978-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1978 (see note 1, Table C15 for detailed explanation).

TABLE H1. ROCKWOOD
1904, via San Pedro, Los Angeles, Colton, Mecca, and Old Beach (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.4031 1/	-0.0022
San Pedro tide station	Castle and others (1986)	--	Tidal 8 - BMA	+3.4248	.0000
San Pedro - Colton	USGS 19th Ann. Rept. 2/	1897	BMA - 978	+291.3984	+.0170
Colton - Old Beach	USGS summary book 9488 2/	10-11/1902	978 - -105	-330.2304	+.0058
Old Beach - Rockwood	USGS summary book 5819 2/	1904	-105 - -162Y	-17.288 3/	-.0005
			Sum =	-49.2153	+0.0201
	Orthometrically corrected height for -162Y =			-49.1952 m	

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1904-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1904 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

2/ Third-order.

3/ This 1904 elevation difference is based on the most likely interpretation of the original elevation values for bench mark -162Y in USGS summary book 5819 (p. 2). Because the entries for this mark have been repeatedly adjusted and readjusted (overwritten), clear identification of the original notes of the survey crew is particularly difficult and other possible interpretations produce values of -17.295 and -17.334. These other possible interpretations are shown as open circle 1904 heights in fig. 13.

TABLE H2. ROCKWOOD
1905, via San Pedro, Los Angeles, Colton, Mecca, and Old Beach (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.4015 1/	-0.0022
San Pedro tide station	Castle and others (1986)	--	Tidal 8 - BMA	+3.4248	.0000
San Pedro - Colton	USGS 19th Ann. Rept. 2/	1897	BMA - 978	+291.3984	+.0170
Colton - Old Beach	USGS summary book 9488 2/	10-11/1902	978 - -105	-330.2304	+.0058
Old Beach - Rockwood	USGS summary book 5820 2/	1904	-105 - -162Y	-17.264	-.0005
			Sum =	-49.1897	+0.0201
	Orthometrically corrected height for -162Y =			-49.1696 m	

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1905-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1905 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

2/ Third-order.

TABLE H3. ROCKWOOD
1927, via Jacumba and El Centro (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - El Centro	82606	12/1926-3/27	M57 - T59	-19.0695	+0.0183
El Centro - Rockwood	L-11	1-3/1928	T59 - -162Y	-36.0724	+.0014
			Sum =	-49.2589	+0.0197
	Orthometrically corrected height for -162Y =			-49.2392 m	

TABLE H4. ROCKWOOD
1928, via La Mesa, Santa Ysabel, Aguanga, Indio, and Niland (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Aguanga	82706	7-9/1927	M57 - A63	+589.1551	+0.0343
Aguanga - Indio	L-8615[1/]	4/1939	A63 - -15T	-599.3445	-.0336
Indio - Rockwood	L-11	1-3/1928	-15T - -162Y	-44.9135	+.0012
			Sum =	-49.2199	+0.0019
	Orthometrically corrected height for -162Y =			-49.2180 m	

Notes:

1/ Second-order.

TABLE H5. ROCKWOOD
1938, via San Ysidro, Campo, Pine Valley, Jacumba, and El Centro (4)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	82606	12/1926-3/27	M57 - W57	+27.3923[1/]	+0.0003
San Ysidro - Campo	USGS summary book 7802[2/]	10-11/1938	W57 - Y57	+647.0517	+.0579
Campo area	82606	12/1926-3/27	Y57 - B58	+139.6945	+.0258
Campo - Pine Valley	USGS summary book 7820[2/]	11-12/1938	B58 - 3211.1	+158.8496	+.0111
Pine Valley - Jacumba	L-8528[3/]	2-4/1939	3211.1 - Q58	-105.9925	+.0204
Jacumba - El Centro	L-222	2-3/1931	Q58 - R59	-884.9965	-.0810
El Centro - Rockwood	L-222	2-3/1931	R59 - -162Y	-36.9630	+.0014
			Sum =	-49.0134	+0.0359
	Orthometrically corrected height for -162Y =			-48.9775 m	

Notes:

1/ The 1926/1927 elevation difference has been corrected to a 1938-equivalent by correcting for 0.051 m of uplift east of the La Nacion fault at the San Ysidro junction mark between 1926/1927, and 1938 (see text for details).

2/ Third-order.

3/ Second-order.

TABLE H6. ROCKWOOD
1939, via Santa Ysabel, Julian, and Truckhaven (5)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Santa Ysabel	Tables J2-J9	1938	LMSL - J62	+909.6475[1/]	0.0000
Santa Ysabel - Julian	L-8528[2/]	2-4/1939	J62 - H308	+376.7574	+0.0817
Julian - Truckhaven	L-8582[2/]	3/1939	H308 - V577	-1340.6596	-.1226
Truckhaven - Rockwood	L-8583[2/]	3/1939	V577 - -162Y	+5.3957	+.0004
			Sum =	-48.8590	-0.0405
	Orthometrically corrected height for -162Y =			-48.8995 m	

Notes:

1/ This averaged 1938 orthometric height is based on the mean value of the 8 alternative 1938/1939 heights developed for Santa Ysabel (Tables J2-J9).

2/ Second-order.

TABLE H7. ROCKWOOD
1955, via Miramar, Ramona, Julian, and Truckhaven (6)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-15549.1	3-4/1955	M57 - U896	+140.6823	+0.0011
Miramar - Poway	L-15543.3 1/	3/1955	U896 - F321	-11.3796	-.0003
Poway - Woodson	L-15543.5 1/	3/1955	F321 - C282	+303.0515	+.0135
Woodson - Ramona	L-15546	2-3/1955	C282 - A62	-6.4376	-.0009
Ramona - Truckhaven	L-15872	3-4/1956	A62 - D579	-433.5799	+.0221
Truckhaven area	L-15875	1-3/1956	D579 - V577	-52.7125	+.0005
Truckhaven - Rockwood	L-8583 1/	3/1939	V577 - -162Y	+5.3957	+.0004
			Sum =	-49.0971	+0.0364
	Orthometrically corrected height for -162Y =			-49.0607 m	

Notes:

1/ Second-order.

TABLE H8. ROCKWOOD
1956, via La Mesa, Ramona, Julian, and Truckhaven (7)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Ramona	L-15546	2-3/1955	M57 - A62	+425.9435	+0.0104
Ramona - Truckhaven	L-15872	3-4/1956	A62 - D579	-433.5799	+.0221
Truckhaven area	L-15875	1-3/1956	D579 - V577	-52.7125	+.0005
Truckhaven - Rockwood	L-8583 1/	3/1939	V577 - -162Y	+5.3957	+.0004
			Sum =	-49.0702	+0.0334
	Orthometrically corrected height for -162Y =			-49.0368 m	

Notes:

1/ Second-order.

TABLE H9. ROCKWOOD
1972, via Hassayampa, Salome, Blythe, Palo Verde, Ogilby, and El Centro (8)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Hassayampa	Tables B2-B4	--	LMSL - 010	+274.5661[1/]	0.0000
Hassayampa - Burning Well	L-24555.3	3-4/1981	010 - R476	+101.4902[2/]	+0.0010
Burning Well - Salome	L-24562.3	12/1981-1/82	R476 - A478	+184.6105[2/]	+.0045
Salome - Palo Verde	L-24562.2	11-12/1981	A478 - S1231	-340.2187[2/]	-.0190
Palo Verde - Ogilby	L-22668	2-4/1972	S1231 - L133	-85.3218	-.0030
Ogilby - El Centro	L-22603	10/1971-1/72	L133 - W89	-147.4277	-.0003
El Centro - Rockwood	L-22606	1-2/1972	W89 - M69	-36.3928	+.0014
Rockwood area	L-9173	5-6/1941	M69 - -162Y	-0.5242	.0000
			Sum =	-49.2184	-0.0148
	Orthometrically corrected height for -162Y =			-49.2332 m	

Notes:

1/ This orthometric height is based on the mean value of the 3 first-order heights reconstructed for the Hassayampa reference mark (Tables B2-B4).

2/ These 1981 elevation differences are assumed to be 1972-equivalents. This interpretation indicates that Palo Verde sustained net uplift of some 0.12 m between 1933 and 1972 with respect to an invariant reference point such as San Diego (see text for details). If Palo Verde was assumed to have remained fixed between 1933 and 1972 (i.e., that all or most of the apparent uplift occurred after 1972), an alternative open circle 1972 height would plot 0.1222 m lower (see fig. 13).

TABLE H10. ROCKWOOD
1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, Mecca, and Salton City (9)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3284[1/]	-0.0022
San Pedro area	L-23644	1-2/1974	Tidal 8 - 21-03690	+9.7053	+.0001
San Pedro - Los Angeles	L-23611	1-3/1974	21-03690 - 338	+90.3218	-.0001
Los Angeles - San Fernando	L-23614	7-11/1973	338 - 04-00855	+276.0888	+.0162
San Fernando - Saugus	L-23691	3-7/1973	04-00855 - 1171	-22.8927	-.0013
Saugus - Palmdale	L-23679	11/1972-3/73	1171 - Loft	+550.5059	+.0524
Palmdale - LA Co. line	L-23671	10/1973-2/74	Loft - M487	-203.5111	-.0292
LA Co. line - Rosamond	L-23685	2-10/1974	M487 - E1147	+34.2195	+.0050
Rosamond - Barstow	L-23208	11/1973-2/74	E1147 - F43	-95.8787	-.0177
Barstow - Amboy	L-23227	2-3/1974	F43 - T1250	-456.3090	-.0224
Amboy - Mecca	L-23315	3-5/1974	T1250 - K572	-244.2525	+.0347
Mecca - Imp. Co. line	L-23501	5-9/1974	K572 - W572	+21.1712	+.0003
Imp. Co. line - Salton City	L-23349	3/1974	W572 - G577	+15.7785	+.0002
Salton City - Westmorland	L-23361	12/1973-4/74	G577 - F578r	-26.9608	+.0004
Westmorland area	L-23712	2/1975	F578r - H578	+0.7132	.0000
Westmorland area	L-23361	12/1973-4/74	H578 - M578	-3.8867	.0000
Westmorland - Rockwood	L-23343	12/1973-1/74	M578 - F611r	+4.0558	.0000
Rockwood area	L-23243	12/1973-1/74	F611r - M69	-0.9431	.0000
Rockwood area	L-9173	5-6/1941	M69 - -162Y	-0.5242	.0000
			Sum =	-49.0442	+0.0364
	Orthometrically corrected height for -162Y =			-49.0078 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1974-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1974 (see note 1, Table C15 for detailed explanation).

TABLE H11. ROCKWOOD

1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, Mecca, and Niland (10)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3284[1/]	-0.0022
San Pedro area	L-23644	1-2/1974	Tidal 8 - 21-03690	+9.7053	+.0001
San Pedro - Los Angeles	L-23611	1-3/1974	21-03690 - 338	+90.3218	-.0001
Los Angeles - San Fernando	L-23614	7-11/1973	338 - 04-00855	+276.0888	+.0162
San Fernando - Saugus	L-23691	3-7/1973	04-00855 - 1171	-22.8927	-.0013
Saugus - Palmdale	L-23679	11/1972-3/73	1171 - Loft	+550.5059	+.0524
Palmdale - LA Co. line	L-23671	10/1973-2/74	Loft - M487	-203.5111	-.0292
LA Co. line - Rosamond	L-23685	2-10/1974	M487 - E1147	+34.2195	+.0050
Rosamond - Barstow	L-23208	11/1973-2/74	E1147 - F43	-95.8787	-.0177
Barstow - Amboy	L-23227	2-3/1974	F43 - T1250	-456.3090	-.0224
Amboy - Frink	L-23315	3-5/1974	T1250 - V614	-244.1347	+.0347
Frink - Rockwood	L-23243	12/1973-2/74	V614 - M69	+9.9056	-.0005
Rockwood area	L-9173	5-6/1941	M69 - -162Y	-0.5242	.0000
			Sum =	-48.9489	+0.0350
	Orthometrically corrected height for -162Y =			-48.9139 m	

Notes:

[1/] The 1968/1969 elevation difference has been corrected to a 1974-equivalent by allowing for relative movement known to have occurred between San Diego, and San Pedro from 1968/1969 to 1974 (see note 1, Table C15 for detailed explanation).

TABLE H12. ROCKWOOD
1976, via Bill Williams River, Freda Junction, Cottonwood Pass, Mecca, and Niland (11)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - 22Q	Tables A1-A4	--	LMSL - 22Q	+186.7030[1/]	0.0000
22Q - 21N	L-24068	5-6/1976	22Q - 21N	+120.4695	+0.0065
21N - 20W	L-24085	9-10/1975	21N - 20W	-7.0468	-.0008
20W - Freda Junc.	L-24077	4-5/1976	20W - 10M	-35.9718	-.0022
Freda Junc. - Cot. P.	L-24080	4-6/1976	1DM - J1254	+213.3835	+.0344
Cot. P. - Frink	L-24071	5-6/1976	J1254 - V614	-536.8244	-.0234
Frink - Rockwood	L-24130.1	11/1976-1/77	V614 - M69	+9.9116	-.0005
Rockwood area	L-9173	5-6/1941	M69 - -162Y	-0.5242	.0000
			Sum =	-48.9996	+0.0140
	Orthometrically corrected height for -162Y =			-48.9856 m	

Notes:

1/ This averaged orthometric height is based on the mean value of the 4 first-order heights reconstructed for the Bill Williams River reference mark (Tables A1-A4).

TABLE H13. ROCKWOOD
1978, via Miramar, Julian, Ocotillo, and El Centro (12)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Rockwood	L-24301.18	1-5/1978	M1305 - M69	-184.0258	+.0735
Rockwood area	L-9173	5-6/1941	M69 - -162Y	-0.5242	.0000
			Sum =	-49.2086	+0.0750
	Orthometrically corrected height for -162Y =			-49.1336 m	

TABLE H14. ROCKWOOD
1978, via Miramar, Julian, Salton City, Mecca, and Niland (13)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Julian	L-24301.18	1-5/1978	M1305 - 4219T	+1151.1644	+.1599
Julian - Mecca	L-24301.19	1-4/1978	4219T - G516r	-1343.6187	-.1293
Mecca - Rockwood	L-24301.18	1-5/1978	G516r - M69	+8.4549	+.0007
Rockwood area	L-9173	5-6/1941	M69 - -162Y	-0.5242	.0000
			Sum =	-49.1822	+0.0328
	Orthometrically corrected height for -162Y =			-49.1494 m	

TABLE H15. ROCKWOOD
1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cottonwood Pass, Mecca, and Niland (10)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968	M57 - Tidal 8	-2.3222 1/	-0.0022
San Pedro area	L-24301.1	1-5/1978	Tidal 8 - 21-03269	+8.8482	+.0002
San Pedro - Mojave	L-24301.6	1-4/1978	21-03269 - Q49	+835.5896	+.0423
Mojave - Barstow	L-24301.13	1-4/1978	Q49 - GagStn	-203.6716	-.0192
Barstow - Cot. P.	L-24301.23	1-4/1978	GagStn - D723	-101.7026	+.0430
Cot. P. - Mecca	L-24301.28	1-4/1978	D723 - G516r	-599.7839	-.0320
Mecca - Rockwood	L-24301.18	1-5/1978	G516r - M69	+8.4549	+.0007
Rockwood area	L-9173	5-6/1941	M69 - -162Y	-0.5242	.0000
			Sum =	-49.2279	+0.0328
	Orthometrically corrected height for -162Y =			-49.1951 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1978-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1978 (see note 1, Table C15 for detailed explanation).

TABLE I1. EL CENTRO
1904, via San Pedro, Los Angeles, Colton, Mecca, and Old Beach (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.4031 1/	-0.0022
San Pedro tide station	Castle and others (1986)	--	Tidal 8 - BMA	+3.4248	.0000
San Pedro - Colton	USGS 19th Ann. Rept. 2/	1897	BMA - 978	+291.3984	+.0170
Colton - Old Beach	USGS summary book 9488 2/	10-11/1902	978 - -105	-330.2304	+.0058
Old Beach - El Centro	USGS summary book 5819 2/	1904	-105 - -50Y	+16.828	-.0019
El Centro area	82606	12/1926-3/27	-50Y - R59	+2.7351	.0000
			Sum =	-12.3642	+0.0187
	Orthometrically corrected height for R59 =			-12.3455 m	

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1904-equivalent by allowing for relative movement known to have occurred between San Diego, and San Pedro from 1904 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

2/ Third-order.

TABLE I2. EL CENTRO
1905, via San Pedro, Los Angeles, Colton, Mecca, and Old Beach (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1931/1932/1933	M57 - Tidal 8	-2.4015 1/	-0.0022
San Pedro tide station	Castle and others (1986)	--	Tidal 8 - 8MA	+3.4248	.0000
San Pedro - Colton	USGS 19th Ann. Rept. 2/	1897	BMA - 978	+291.3984	+.0170
Colton - Old Beach	USGS summary book 9488 2/	10-11/1902	978 - -105	-330.2304	+.0058
Old Beach - El Centro	USGS summary book 5820 2/	3-4/1905	-105 - -50Y	+16.880	-.0019
El Centro area	82606	12/1926-3/27	-50Y - R59	+2.7351	.0000
			Sum =	-12.3106	+0.0187
	Orthometrically corrected height for R59 =			-12.2919 m	

Notes:

1/ The 1931/1932/1933 elevation difference has been corrected to a 1905-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1905 to 1931/1932/1933 (see note 1, Table A3 for detailed explanation).

2/ Third-order.

TABLE I3. EL CENTRO
1927, via San Ysidro, Campo, and Ocotillo (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - El Centro	82606	12/1926-3/27	M57 - R59	-18.1912	+0.0183
			Sum =	-12.3082	+0.0183
	Orthometrically corrected height for R59 =			-12.2899 m	

TABLE I4. EL CENTRO
1935, via Santa Ysabel, Julian, Pine Valley, and Jacumba (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Santa Ysabel	82706	7-9/1927	M57 - J62	+903.5492	+0.0797
Santa Ysabel - Jacumba	L-6004 1/	3-4/1935	J62 - Q58	-36.6032	+.0836
Jacumba - El Centro	L-222	2-3/1931	Q58 - R59	-884.9965	-.0810
			Sum =	-12.1225	+0.0823
	Orthometrically corrected height for R59 =			-12.0402 m	

Notes:

1/ Second-order.

TABLE 15. EL CENTRO
1938, via San Ysidro, Campo, Pine Valley, and Jacumba (4)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	82606	12/1926-3/27	M57 - W57	+27.3923[1/]	+0.0003
San Ysidro - Campo	USGS summary book 7802[2/]	10-11/1938	W57 - Y57	+647.0517	+.0579
Campo area	82606	12/1926-3/27	Y57 - B58	+139.6945	+.0258
Campo - Pine Valley	USGS summary book 7820[2/]	11-12/1938	B58 - 3211.1	+158.8496	+.0111
Pine Valley - Jacumba	L-8528[3/]	2-4/1939	3211.1 - Q58	-105.9925	+.0204
Jacumba - El Centro	L-222	2-3/1931	Q58 - R59	-884.9965	-.0810
			Sum =	-12.1179	+0.0345
	Orthometrically corrected height for R59 =			-12.0834 m	

Notes:

1/ The 1926/1927 elevation difference has been corrected to a 1938-equivalent by correcting for 0.051 m of uplift east of the La Nacion fault at the San Ysidro junction mark between 1926/1927 and 1938 (see text for details).

2/ Third-order.

3/ Second-order.

TABLE 16. EL CENTRO
1939, via Santa Ysabel, Julian, Pine Valley, and Jacumba (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Santa Ysabel	Tables J2-J9	1938	LMSL - J62	+909.6475[1/]	0.0000
Santa Ysabel - Jacumba	L-8528[2/]	2-4/1939	J62 - Q58	-36.6702	+0.0836
Jacumba - El Centro	L-222	2-3/1931	Q58 - R59	-884.9965	-.0810
			Sum =	-12.0192	+0.0026
	Orthometrically corrected height for R59 =			-12.0166 m	

Notes:

1/ This averaged 1938 orthometric height is based on the mean value of the 8 alternative 1938/1939 heights developed for Santa Ysabel (Tables J2-J9).

2/ Second-order.

TABLE 17. EL CENTRO
1939, via Santa Ysabel, Julian, Truckhaven, and Rockwood (5)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Santa Ysabel	Tables J2-J9	1938	LMSL - J62	+909.6475[1]	0.0000
Santa Ysabel - Julian	L-8528[2]	2-4/1939	J62 - H308	+1376.7574	+0.0817
Julian - Truckhaven	L-8582[2]	3/1939	H308 - V577	-1340.6596	-.1226
Truckhaven - Rockwood	L-8583[2]	3/1939	V577 - M69	+5.8979	+.0004
Rockwood - El Centro	L-222	2-3/1931	M69 - R59	+36.4634	-.0014
			Sum =	-11.8934	-0.0419
	Orthometrically corrected height for R59 =			-11.9353 m	

Notes:

1/ This averaged 1938 orthometric height is based on the mean value of the 8 alternative 1938/1939 heights developed for Santa Ysabel (Tables J2-J9).

2/ Second-order.

TABLE 18. EL CENTRO
1955, via San Ysidro, Campo, Pine Valley, and Jacumba (4)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	L-15549.4	2/1955	M57 - K741	+151.5104	+0.0017
San Ysidro - Jamul	L-15540.13[1]	2/1955	K741 - L891	+7.8993	-.0007
Jamul - Dulzura	L.15540.12[1]	2/1955	L891 - 1CSHD	+53.2248	+.0013
Dulzura - Campo	L-15540.8[1]	2-3/1955	1CSHD - Y57	+461.6744	+.0559
Campo area	82606	12/1926-3/27	Y57 - A58	+101.5100	+.0188
Campo - Morena	L-15540.3[1]	3/1955	A58 - V893	+64.4346	+.0064
Morena - Pine Valley	L-15540.15[1]	3/1955	V893 - A309	+163.4931	+.0117
Pine Valley - Jacumba	L-8528[1]	2-4/1939	A309 - Q58	-136.9116	+.0204
Jacumba - El Centro	L-9179	5-6/1941	Q58 - R59	-884.9901	-.0810
			Sum =	-12.2721	+0.0345
	Orthometrically corrected height for R59 =			-12.2376 m	

Notes:

1/ Second-order.

TABLE I9. EL CENTRO
1956, via La Mesa, Julian, Truckhaven, and Rockwood (6)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Ramona	L-15546	2-3/1955	M57 - A62	+425.9435	+0.0104
Ramona - Truckhaven	L-15872	3-4/1956	A62 - D579	-433.5799	+.0221
Truckhaven area	L-15875	1-3/1956	D579 - V577	-52.7125	+.0005
Truckhaven - Rockwood	L-8583 1/	3/1939	V577 - M69	+5.8979	+.0004
Rockwood - El Centro	L-9173	5-6/1941	M69 - R59	+36.4110 2/	-.0014
			Sum =	-12.1570	+0.0320
	Orthometrically corrected height for R59 =			-12.1250 m	

Notes:

1/ Second-order.

2/ The 1941 elevation difference has been corrected to a 1956-equivalent by correcting for an 0.0689-m increase in this elevation difference due to continued postseismic movement across the Imperial fault during the period 1941-1956 following the 1940 earthquake (fig. 31).

TABLE I10. EL CENTRO
1972, via Hassayampa, Salome, Blythe, Palo Verde, and Ogilby (7)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Hassayampa	Tables B2-B4	--	LMSL - 010	+274.5661 1/	0.0000
Hassayampa - Burning Well	L-24555.3	3-4/1981	010 - R476	+101.4902 2/	+0.0010
Burning Well - Salome	L-24562.3	12/1981-1/82	R476 - A478	+184.6105 2/	+.0045
Salome - Palo Verde	L-24562.2	11-12/1981	A478 - S1231	-340.2187 2/	-.0190
Palo Verde - Ogilby	L-22668	2-4/1972	S1231 - L133	-85.321B	-.0030
Ogilby - El Centro	L-22603	10/1971-1/72	L133 - R59	-147.3578	+.0003
			Sum =	-12.2315	-0.0162
	Orthometrically corrected height for R59 =			-12.2477 m	

Notes:

1/ This averaged orthometric height is based on the mean value of the 3 first-order heights reconstructed for the Hassayampa reference mark (Tables B2-B4).

2/ These 1981 elevation differences are assumed to be 1972-equivalents. This interpretation indicates that Palo Verde sustained net uplift of some 0.12 m between 1933 and 1972 with respect to an invariant reference point such as San Diego (see text for details). If Palo Verde was assumed to have remained fixed between 1933 and 1972 (i.e., that all or most of the apparent uplift occurred after 1972), an alternative open circle 1972 height would plot 0.1222 m lower (see fig. 14).

TABLE I11. EL CENTRO
1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms, Cotton Wood Pass, Mecca, and Niland (8)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3284 1/	-0.0022
San Pedro area	L-23644	1-2/1974	Tidal 8 - 21-03690	+9.7053	+.0001
San Pedro - Los Angeles	L-23611	1-3/1974	21-03690 - 338	+90.3218	-.0001
Los Angeles - San Fernando	L-23614	7-11/1973	338 - 04-00855	+276.0888	+.0162
San Fernando - Saugus	L-23691	3-7/1973	04-00855 - 1171	-22.8927	-.0013
Saugus - Palmdale	L-23679	11/1972-3/73	1171 - Loft	+550.5059	+.0524
Palmdale - LA Co. line	L-23671	10/1973-2/74	Loft - M487	-203.5111	-.0292
LA Co. line - Rosamond	L-23685	2-10/1974	M487 - E1147	+34.2195	+.0050
Rosamond - Barstow	L-23208	11/1973-2/74	E1147 - F43	-95.8787	-.0177
Barstow - Amboy	L-23227	2-3/1974	F43 - T1250	-456.3090	-.0224
Amboy - Frink	L-23315	3-5/1974	T1250 - V614	-244.1347	+.0347
Frink - El Centro	L-23243	12/1973-2/74	V614 - R59	+46.4194	-.0020
			Sum =	-11.9109	+0.0335
	Orthometrically corrected height for R59 =			-11.8774 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1974-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1974 (see note 1, Table C15 for detailed explanation).

TABLE I12. EL CENTRO
1976, via Bill Williams River, Freda Junction, Cottonwood Pass, Mecca, and Niland (9)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - 22Q	Tables A1-A4	--	LMSL - 22Q	+186.7030 1/	0.0000
22Q - 21N	L-24068	5-6/1976	22Q - 21N	+120.4695	+0.0065
21N - 20W	L-24085	9-10/1975	21N - 20W	-7.0468	-.0008
20W - Freda Junc.	L-24077	4-5/1976	20W - 10M	-35.0718	-.0022
Freda Junc. - Cot. P.	L-24080	4-6/1976	10M - J1254	+213.3835	+.0344
Cot. P. - Frink	L-24071	5-6/1976	J1254 - V614	-536.8244	-.0234
Frink - El Centro	L-24130.1	11/1976-1/77	V614 - R59	+46.4720	-.0020
			Sum =	-11.9150	+0.0125
	Orthometrically corrected height for R59 =			-11.9025 m	

Notes:

1/ This averaged orthometric height is based on the mean value of the 4 first-order heights reconstructed for the Bill Williams River reference mark (Tables A1-A4).

TABLE 113. EL CENTRO
1978, via Miramar, Julian, and Ocotillo (10)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Julian - El Centro	L-24301.18	1-5/1978	M1305 - R59	-147.6152	+.0777
			Sum =	-12.2738	+0.0792
	Orthometrically corrected height for R59 =			-12.1946 m	

TABLE 114. EL CENTRO
1978, via Miramar, Julian, Salton City, Mecca, and Niland (11)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Julian	L-24301.18	1-5/1978	M1305 - 4219T	+1151.1644	+.1599
Julian - Truckhaven - Mecca	L-24301.19	1-4/1978	4219T - G516	-1343.6187	-.1293
Mecca - El Centro	L-24301.18	1-5/1978	G516 - R59	+44.9386	-.0005
			Sum =	-12.1743	+0.0316
	Orthometrically corrected height for R59 =			-12.1427 m	

TABLE I15. EL CENTRO
1978, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, Twentynine Palms Cottonwood Pass, Mecca, and Niland (8)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3222 [1/]	-0.0022
San Pedro area	L-24301.1	1-5/1978	Tidal 8 - 21-03269	+8.8482	+.0002
San Pedro - Mojave	L-24301.6	1-4/1978	21-03269 - Q49	+835.5896	+.0423
Mojave - Barstow	L-24301.13	1-4/1978	Q49 - GagStn	-203.6716	-.0192
Barstow - Cot. P.	L-24301.23	1-4/1978	GagStn - D723	-101.7026	+.0430
Cot. P. - Mecca	L-24301.28	1-4/1978	D723 - G516r	-599.7839	-.0320
Mecca - El Centro	L-24301.18	1-5/1978	G516r - R59	+44.9386	-.0005
			Sum =	-12.2209	+0.0316
	Orthometrically corrected height for R59 =			-12.1893 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1978-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1978 (see note 1, Table C15 for detailed explanation).

TABLE I16. EL CENTRO
1981, via Hassayampa and Yuma (12)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - Hassayampa	Tables B2-B4	--	LMSL - O10	+274.5661 [1/]	0.0000
Hassayampa - Gila Bend	L-24555.3	3-4/1981	O10 - A14	-49.2808	+0.0062
Gila Bend - El Centro	L-24562.1	3-5/1981	A14 - R59	-237.4664	-.0065
			Sum =	-12.1811	-0.0003
	Orthometrically corrected height for R59 =			-12.1814 m	

Notes:

1/ This Averaged orthometric height is based on the mean value of the 3 first-order heights reconstructed for the Hassayampa reference mark (Tables B2-B4).

TABLE J1. SANTA YSABEL
1927, via La Mesa and Ramona (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Santa Ysabel	82706	7-9/1927	M57 - J62	+903.5942	+0.0797
			Sum =	+909.4772	+0.0797
	Orthometrically corrected height for J62 =			+909.5569 m	

TABLE J2. SANTA YSABEL
1938, via Grantville, Poway, Ramona, Barona Valley, Tule Springs, and Julian (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Grantville	82706	7-9/1927	M57 - J61	+106.3572	+0.0007
Grantville - Poway	USGS summary book 7799 1/	8-9/1938	J61 - 516.2	+45.0891	-.0022
Poway area	USGS summary book 7800 1/	8-10/1938	516.2 - 766.2	+76.2135	-.0008
Poway - Ramona	USGS summary book 7802 1/	10-11/1938	766.2 - Z61	+202.8322	+.0119
Ramona area	82706	7-9/1927	Z61 - B62	+3.3240	+.0008
Ramona - Barona Valley	USGS summary book 7820 1/	11-12/1938	B62 - S51	+83.8362	+.0050
Barona Valley - Tule Springs	L-8590 2/	3-4/1939	S51 - S29	-271.0205	-.0120
Tule Springs - Julian	USGS summary book 7820 1/	11-12/1938	S29 - G308	+945.2592	+.0800
Julian - Santa Ysabel	L-8528 2/	2-4/1939	G308 - J62	-288.1502	-.0547
			Sum =	+909.6237	+0.0287
	Orthometrically corrected height for J62 =			+909.6524 m	

1/ Third-order.

2/ Second-order.

TABLE J3. SANTA YSABEL
1938, via Grantville, Santee, Poway, Ramona, Barona Valley, Tule Springs, and Julian (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Grantville	82706	7-9/1927	M57 - J61	+106.3572	+0.0007
Grantville area	USGS summary book 7799 1/	8-9/1938	J61 - 79.2	+88.1070	-.0015
Grantville - Santee	USGS summary book 7800 1/	8-10/1938	79.2 - W321	+75.4178	+.0002
Santee - Poway	USGS summary book 7819 1/	9-10/1938	W321 - H42	+149.4633	-.0017
Poway area	USGS summary book 7800 1/	8-10/1938	H42 - 766.2	-15.4460	+.0003
Poway - Ramona	USGS summary book 7802 1/	10-11/1938	766.2 - Z61	+202.8322	+.0119
Ramona area	82706	7-9/1927	Z61 - B62	+3.3240	+.0008
Ramona - Barona Valley	USGS summary book 7820 1/	11-12/1938	B62 - S51	+83.8362	+.0050
Barona Valley - Tule Springs	L-8590 2/	3-4/1939	S51 - S29	-271.0205	-.0120
Tule Springs - Julian	USGS summary book 7820 1/	11-12/1938	S29 - G308	+945.2592	+.0800
Julian - Santa Ysabel	L-8528 2/	2-4/1939	G308 - J62	-288.1502	-.0547
			Sum =	+909.6492	+0.0290
	Orthometrically corrected height for J62 =			+909.6782 m	

Notes:

1/ Third-order.

2/ Second-order.

TABLE J4. SANTA YSABEL
1938, via Grantville, Santee, Lakeside, Barona Valley, Tule Springs, and Julian (4)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego area	82706	7-9/1927	M57 - J61	+106.3572	+0.0007
San Diego - Grantville	USGS summary book 7799 1/	8-9/1938	J61 - 79.2	-88.1070	-.0015
Grantville - Santee	USGS summary book 7800 1/	8-10/1938	79.2 - R61	+88.2340	+.0009
Santee - Lakeside	82706	7-9/1927	R61 - T61	+11.3852	+.0008
Lakeside - Barona Valley	USGS summary book 7820 1/	11-12/1938	T61 - S51	+399.8086	+.0200
Barona Valley - Tule Springs	L-8590 2/	3-4/1939	S51 - S29	-271.0205	-.0120
Tule Springs - Julian	USGS summary book 7820 1/	11-12/1938	S29 - G308	+945.2592	+.0800
Julian - Santa Ysabel	L-8528 2/	2-4/1939	G308 - J62	-288.1502	-.0547
			Sum =	+909.6495	+0.0342
	Orthometrically corrected height for J62 =			+909.6837 m	

Notes:

1/ Third-order.

2/ Second-order.

TABLE J5. SANTA YSABEL
1939, via La Mesa, Jamul, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian (5)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - La Mesa	82706	7-9/1927	M57 - M61	+158.6868	-0.0003
La Mesa - Campo	USGS summary book 7802 1/	10-11/1938	M61 - Y57	+515.8215	+0.0614
Campo area	82606	12/1926-3/27	Y57 - B58	+139.6945	+.0258
Campo - Pine Valley	USGS summary book 7820 1/	11-12/1938	B58 - 3211.1	+158.8496	+.0111
Pine Valley - Santa	L-8528 2/	2-4/1939	3211.1 - J62	-69.3223	-.0632
			Sum =	+909.6131	+0.0351
	Orthometrically corrected height for J62 =			+909.6482 m	

Notes:

1/ Third-order.

2/ Second-order.

TABLE J6. SANTA YSABEL
1939, via National City, La Presa, Jamul, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian (6)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - National City	82606	12/1926-3/27	M57 - R57	+0.1550	+0.0001
National City - Jamul	USGS summary book 7801 1/	9-10/1938	R57 - 997	+297.7997	+.0100
Jamul - Campo	USGS summary book 7802 1/	10-11/1938	997 - Y57	+376.6212	+.0502
Campo area	82606	12/1926-3/27	Y57 - B58	+139.6945	+.0258
Campo - Pine Valley	USGS summary book 7820 1/	11-12/1938	B58 - 3211.1	+158.8496	+.0111
Pine Valley - Santa Ysabel	L-8528 2/	1-4/1939	3211.1 - J62	-69.3223	-.0632
			Sum =	+909.6807	+0.0339
	Orthometrically corrected height for J62 =			+909.7146 m	

Notes:

1/ Third-order.

2/ Second-order.

TABLE J7. SANTA YSABEL
1939, via Chula Vista, Jamul, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian (7)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Chula Vista	82606	12/1926-3/27	M57 - S57	+3.7572	+0.0001
Chula Vista - Jamul	USGS summary book 7801 1/	9-10/1938	S57 - 997	+294.1128	+.0100
Jamul - Campo	USGS summary book 7802 1/	10-11/1938	997 - Y57	+376.6212	+.0502
Campo area	82606	12/1926-3/27	Y57 - B58	+139.6945	+.0258
Campo - Pine Valley	USGS summary book 7820 1/	11-12/1938	B58 - 3211.1	+158.8496	+.0111
Pine Valley - Santa Ysabel	L-8528 2/	2-4/1939	3211.1 - J62	-69.3223	-.0632
			Sum =	+909.5960	+0.0339
	Orthometrically corrected height for J62 =			+909.6299 m	

Notes:

1/ Third-order.

2/ Second-order.

TABLE J8. SANTA YSABEL
1939, via Chula Vista, Otay Dam, Kuebler Ranch, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian (8)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Chula Vista	82606	12/1926-3/27	M57 - S57	+3.7572	+0.0001
Chula Vista - Kuebler Ranch	USGS summary book 7801[1/]	9-10/1938	S57 - H87	+222.5952	+.0100
Kuebler Ranch - Campo	USGS summary book 7802[1/]	10-11/1938	H87 - Y57	+448.0917	+.0601
Campo area	82606	12/1926-3/27	Y57 - B58	+139.6945	+.0258
Campo - Pine Valley	USGS summary book 7820[1/]	11-12/1938	B58 - 3211.1	+158.8496	+.0111
Pine Valley - Santa Ysabel	L-8528[2/]	2-4/1939	3211.1 - J62	-69.3223	-.0632
			Sum =	+909.5489	+0.0438
	Orthometrically corrected height for J62 =			+909.5927 m	

Notes:

1/ Third-order.

2/ Second-order.

TABLE J9. SANTA YSABEL
1939, via San Ysidro, Kuebler Ranch, Dulzura, Barrett Junction, Campo, Pine Valley, and Julian (9)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	82606	12/1926-3/27	M57 - W57	+27.3923[3/]	+0.0003
San Ysidro - Campo	USGS summary book 7802[1/]	10-11/1938	W57 - Y57	+647.0517	+.0582
Campo area	82606	12/1926-3/27	Y57 - B58	+139.6945	+.0258
Campo - Pine Valley	USGS summary book 7820[1/]	11-12/1958	B58 - 3211.1	+158.8496	+.0111
Pine Valley - Santa Ysabel	L-8528[2/]	2-4/1939	3211.1 - J62	-69.3223	-.0632
			Sum =	+909.5488	+0.0318
	Orthometrically corrected height for J62 =			+909.5806 m	

Notes:

1/ Third-order.

2/ Second-order.

3/ The 1927 elevation difference has been corrected to a 1938-equivalent by correcting for an 0.051-m uplift east of the La Nacion fault at the San Ysidro junction mark between 1927 and 1938 (see text for details).

TABLE J10. SANTA YSABEL
1955, via Miramar and Ramona (10)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-15549.1	3-4/1955	M57 - U896	+140.6823	+0.0011
Miramar - Poway	L-15543.3 1/	3/1955	U896 - F321	-11.3796	-.0003
Poway - Woodson	L-15543.5 1/	3/1955	F321 - C282	+303.0515	+.0135
Woodson - Ramona	L-15546	2-3/1955	C282 - A62	-6.4376	-.0009
Ramona - Santa Ysabel	L-15872	3-4/1956	A62 - J62	+477.6197	+.0672
			Sum =	+909.4193	+0.0806
	Orthometrically corrected height for J62 =			+909.4999 m	

Notes:

1/ Second-order.

TABLE J11. SANTA YSABEL
1956, via La Mesa and Ramona (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Ramona	L-15546	2-3/1955	M57 - A62	+425.9435	+0.0104
Ramona - Santa Ysabel	L-15872	3-4/1956	A62 - J62	+477.6197	+.0672
			Sum =	+909.4462	+0.0776
	Orthometrically corrected height for J62 =			+909.5238 m	

TABLE J12. SANTA YSABEL
1968, via San Ysidro, Campo, and Julian (11)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	L-21529	6-10/1968	M57 - SD241	-2.9503	+0.0002
San Ysidro - Santa Ysabel	L-21532	11/1968-3/70	SD241 - J62	+906.5715	+.0303
			Sum =	+909.5042	+0.0305
	Orthometrically corrected height for J62 =			+909.5347 m	

TABLE J13. SANTA YSABEL
1969, via Miramar and Ramona (10)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-21529	6-10/1968	M57 - H895	+116.4381	+0.0019
Miramar - Santa Ysabel	L-22379	4/1970-3/71	H895 - J62	+787.1405	+.0794
			Sum =	+909.4616	+0.0813
	Orthometrically corrected height for J62 =			+909.5429 m	

TABLE J14. SANTA YSABEL
1969, via Oceanside and Pala (12)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Oceanside	L-21529	6-10/1968	M57 - R	+13.7804	+0.0002
Oceanside - Santa Ysabel	L-21532	11/1968-3/70	R - J62	+889.7764	+0.0955
			Sum =	+909.4398	+0.0957
	Orthometrically corrected height for J62 =			+909.5355 m	

TABLE J15. SANTA YSABEL
1978, via Miramar and Ramona (10)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Santa Ysabel	L-24301.18	1-5/1978	M1305 - J62	+774.1030	+.0791
			Sum =	+909.4444	+0.0806
	Orthometrically corrected height for J62 =			+909.5250 m	

TABLE K1. CAMPO
1901, via Otay, Jamul, and Potrero (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego area	82606	12/1926-3/27	M57 - 42SD	+6.9649	.0000
San Diego - Otay	USGS summary book 9221 1/	6/1901-3/02	42SD - 55	+3.9362	.0000
Otay - Potrero	USGS summary book 9131 1/	12/1901-2/02	55 - 2323	+691.3026	+0.0464
Potrero - Campo	L-15540.8 2/	12/1954-1/55	2323 - Y57	-27.7471	+.0118
			Sum =	+680.3396	+0.0582
	Orthometrically corrected height for Y57 =			+680.3978 m	

Notes:

1/ Third-order.

2/ Second-order.

TABLE K2. CAMPO
1902, via Otay, Jamul, and Potrero (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego area	82606	12/1926-3/27	M57 - 42SD	+6.9649	.0000
San Diego - Otay	USGS summary book 9221 1/	6/1901-3/02	42SD - 55	+3.9362	.0000
Otay - 2543	USGS summary book 9131 1/	12/1901-2/02	55 - 2543	+758.3686	+0.0760
2543 - Campo	L-15540.3 2/	3/1955	2543 - Y57	-94.7152	-.0178
			Sum =	+680.4375	+0.0582
	Orthometrically corrected height for Y57 =			+680.4957 m	

Notes:

1/ Third-order.

2/ Second-order.

TABLE K3. CAMPO
1927, via San Ysidro and northern Baja California (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Campo	82606	12/1926-3/27	M57 - Y57	+674.2774	+0.0472
			Sum =	+680.1604	+0.0472
	Orthometrically corrected height for Y57 =			+680.2076 m	

TABLE K4. CAMPO
1938, via La Mesa, Jamul, Dulzura, and Barrett Junction (4)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - La Mesa	82706	7-9/1927	M57 - M61	+158.6868	-0.0003
La Mesa - Campo	USGS summary book 7802 1/	10-11/1938	M61 - Y57	+515.8215	+.0617
			Sum =	+680.3913	+0.0614
	Orthometrically corrected height for Y57 =			+680.4527 m	

Notes:

1/ Third-order.

TABLE K5. CAMPO
1938, via National City, La Presa, Jamul, Dulzura, and Barrett Junction (5)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - National City	82606	12/1926-3/27	M57 - R57	+0.1550	+0.0001
National City - Jamul	USGS summary book 7801 1/	9-10/1938	R57 - 997	+297.7997	+.0060
Jamul - Campo	USGS summary book 7802 1/	10-11/1938	997 - Y57	+376.6212	+.0541
			Sum =	+680.4589	+0.0602
	Orthometrically corrected height for Y57 =			+680.5191 m	

Notes:

1/ Third-order.

TABLE K6. CAMPO
1938, via Chula Vista, Jamul, Dulzura, and Barrett Junction (6)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Chula Vista	82606	12/1927-3/27	M57 - S57	+3.7572	+0.0001
Chula Vista - Jamul	USGS summary book 7801 1/	9-10/1938	S57 - 997	+294.1128	+.0060
Jamul - Campo	USGS summary book 7802 1/	10-11/1938	997 - Y57	+376.6212	+.0541
			Sum =	+680.3742	+0.0602
	Orthometrically corrected height for Y57 =			+680.4344 m	

Notes:

1/ Third-order.

TABLE K7. CAMPO
1938, via Chula Vista, Otay Dam, Kuebler Ranch, Dulzura, and Barrett Junction (7)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Chula Vista	82606	12/1926-3/27	M57 - S57	+3.7572	+0.0001
Chula Vista - Kuebler Ranch	USGS summary	9-10/1938	S57 - H87	+222.5952	+.0200
Kuebler Ranch - Campo	USGS summary book 7802 1/	10-11/1938	H87 - Y57	+448.0917	+.0500
			Sum =	+680.3271	+0.0701
	Orthometrically corrected height for Y57 =			+680.3972 m	

Notes:

1/ Third-order.

TABLE K8. CAMPO
1938, via San Ysidro, Kuebler Ranch, Dulzura, and Barrett Junction (8)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	82606	12/1926-3/27	M57 - W57	+27.3923[1/]	+0.0003
San Ysidro - Campo	USGS summary book 7802[2/]	10-11/1938	W57 - Y57	+647.0517	+.0579
			Sum =	+680.3270	+0.0582
	Orthometrically corrected height for Y57 =			+680.3852 m	

Notes:

1/ The 1927 elevation difference has been corrected to a 1938-equivalent by correcting for an 0.051-m uplift east of the La Nacion fault at the San Ysidro junction mark between 1927 and 1938 (see text for details).

2/ Third-order.

TABLE K9. CAMPO
1955, via San Ysidro, Dulzura, and Barrett Junction (9)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	L-15549.4	2/1955	M57 - K741	+151.5104	+0.0017
San Ysidro - Jamul	L-15540.13[1/]	2/1955	K741 - L891	+7.8993	-.0007
Jamul - Dulzura	L-15540.12[1/]	2/1955	L891 - 1CSHD	+53.2248	+.0013
Dulzura - Campo	L-15540.8[1/]	2-3/1955	1CSHD - Y57	+461.6744	+.0559
			Sum =	+680.1919	+0.0582
	Orthometrically corrected height for Y57 =			+680.2501 m	

Notes:

1/ Second-order.

TABLE K10. CAMPO
1968, via San Ysidro, Dulzura, and Barrett Junction (9)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Ysidro	L-21529	6-10/1968	M57 - SD241	-2.9503	+0.0002
San Ysidro - Campo	L-21532	11/1968-3/70	SD241 - Y57	+677.3201	+.0548
			Sum =	+680.2528	+0.0550
	Orthometrically corrected height for Y57 =			+680.3078 m	

TABLE K11. CAMPO
1974, San Pedro, Los Angeles, Saugus, Mohave, Barstow, Amboy, and Twentynine Palms (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3284 1/	-0.0022
San Pedro area	L-23644	1-2/1974	Tidal 8 - 21-03690	+9.7053	+.0001
San Pedro - Los Angeles	L-23611	1-3/1974	21-03690 - 338	+90.3218	-.0001
Los Angeles - San Fernando	L-23614	7-11/1973	338 - 04-00855	+276.0888	+.0162
San Fernando - Saugus	L-23691	3-7/1973	04-00855 - 1171	-22.8927	-.0013
Saugus - Palmdale	L-23679	11/1972-3/73	1171 - Loft	+550.5059	+.0524
Palmdale - LA Co. line	L-23671	10/1973-2/74	Loft - M487	-203.5111	-.0292
LA Co. line - Rosamond	L-23685	2-10/1974	M487 - E1147	+34.2195	+.0050
Rosamond - Barstow	L-23208	11/1973-2/74	E1147 - F43	-95.8787	-.0177
Barstow - Amboy	L-23227	2-3/1974	F43 - T1250	-456.3090	-.0224
Amboy - Frink	L-23315	3-5/1974	T1250 - V614	-244.1347	+.0347
Frink - El Centro	L-23243	12/1973-2/74	V614 - R59	+46.4194	-.0020
El Centro - Ocotillo	L-23237	2-3/1974	R59 - V612	+956.6169	+.0815
Ocotillo - Pine Valley	L-23283	4-5/1974	V612 - S44	-4.2019	-.0183
Pine Valley - Campo	L-21532	11/1968-3/70	S44 - Y57	-260.0313	-.0328
			Sum =	+680.4728	+0.0639
	Orthometrically corrected height for Y57 =			+680.5367 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1974-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1968/1969 to 1974 (see note 1, Table C15 for detailed explanation).

TABLE K12. CAMPO
1978, via Miramar, Julian, and Pine Valley (11)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Pine Valley	L-24301.18	1-5/1978	M1305 - A309	+874.3583	+.1399
Pine Valley - Campo	L-21532	11/1968-3/70	A309 - Y57	-329.4917	-.0362
			Sum =	+680.2080	+0.1052
	Orthometrically corrected height for Y57 =			+680.3132 m	

TABLE L1. COTTONWOOD PASS
1931, via Bill Williams River, Freda Junction, and Desert Center (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - 22Q	Tables A1-A4	--	LMSL - 22Q	+186.7030[1/]	0.0000
22Q - Cot. P.	L-7407	1931	22Q - 2H	+339.9029	+0.0372
			Sum =	+526.6059	+0.0372
	Orthometrically corrected height for 2H =			+526.6431 m	

Notes:

[1/] This averaged orthometric height is based on the mean value of the 4 first-order heights reconstructed for the Bill Williams River reference mark (Tables A1-A4).

TABLE L2. COTTONWOOD PASS
1961, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, and Twentynine Palms (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3487[1/]	-0.0022
San Pedro - Los Angeles	L-18364	4/1961	Tidal 8 - L1141	+86.3974	-.0011
Los Angeles - Burbank	L-18296	3-5/1961	L1141 - H43	+90.4252	+.0004
Burbank - Mojave	L-18299	3-5/1961	H43 - Q49	+667.5095	+.0460
Mojave - Daggett	L-18230	3-4/1961	Q49 - G293	-237.3754	-.0231
Daggett - Amboy	L-11115	2-4/1944[2/]	G293 - S702	-426.4047	-.0214
Amboy - 29 Palms	L-11067	2-3/1944[2/]	S702 - WWP6	+408.6328	+.0399
29 Palms - Cot. P.	L-11069	2/1944[2/]	WWP6 - 2H	-66.1686	+.0162
			Sum =	+526.5287	+0.0547
	Orthometrically corrected height for 2H =			+526.5834 m	

Notes:

[1/] The 1968/1969 elevation difference has been corrected to a 1961-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1961 to 1968/1969 (see note 1, Table C15 for detailed explanation).

[2/] The small magnitude of circuit misclosures in the eastern Mojave Desert area based on various combinations of 1944 and 1961 levelings suggests that these results may be considered as 1961-equivalents (Castle and others, 1984).

TABLE L3. COTTONWOOD PASS
1974, via San Pedro, Los Angeles, Saugus, Mojave, Barstow, Amboy, and Twentynine Palms (2)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - San Pedro	Table 2	1968/1969	M57 - Tidal 8	-2.3284[1/]	-0.0022
San Pedro area	L-23644	1-2/1974	Tidal 8 - 21-03690	+9.7053	+.0001
San Pedro - Los Angeles	L-23611	1-3/1974	21-03690 - 338	+90.3218	-.0001
Los Angeles - San Fernando	L-23614	7-11/1973	338 - 04-00855	+276.0888	+.0162
San Fernando - Saugus	L-23691	3-7/1973	04-00855 - 1171	-22.8922	-.0013
Saugus - Palmdale	L-23679	11/1972-3/73	1171 - Loft	+550.5059	+.0524
Palmdale - L.A. Co line	L-23671	10/1973-2/74	Loft - M487	-203.5111	-.0292
L.A. Co line - Rosamond	L-23685	2-10/1974	M487 - E1147	+34.2195	+.0050
Rosamond - Barstow	L-23208	11/1973-2/74	E1147 - F43	-95.8787	-.0177
Barstow - Amboy	L-23223	2-3/1974	F43 - T1250	-456.3090	-.0224
Amboy - Cot. P.	L-23315	3-5/1974	T1250 - 2H	+341.1309	+.0597
			Sum =	+526.9353	+0.0605
	Orthometrically corrected height for 2H =			+526.9958 m	

Notes:

1/ The 1968/1969 elevation difference has been corrected to a 1961-equivalent by allowing for relative movement known to have occurred between San Diego and San Pedro from 1961 to 1968/1969 (see note 1, Table C15 for detailed explanation).

TABLE L4. COTTONWOOD PASS
1976, via Bill Williams River, Freda Junction, and Desert Center (1)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego - 22Q	Tables A1-A4	--	LMSL - 22Q	+186.7030[1/]	0.0000
22Q - 21N	L-24068	5-6/1976	22Q - 21N	+120.4695	+0.0065
21N - 20W	L-24085	9-10/1975	21N - 20W	-7.0468	-.0008
20W - Freda Junc.	L-24077	4-5/1976	20W - 10M	-35.0718	-.0022
Freda Junc. - Cot. P.	L-24080	4-6/1976	10M - J1254	+213.3835	+.0344
Cot. P. area	L-24071	5-6/1976	J1254 - D723	+64.3344	+.0072
Cot. P. area	L-23315	3-5/1974	D723 - 2H	-15.8986	-.0058
			Sum =	+526.8732	+0.0393
	Orthometrically corrected height for 2H =			+526.9125 m	

Notes:

1/ This averaged orthometric height is based on the mean value of the 4 first-order heights reconstructed for the Bill Williams River reference mark (Tables A1-A4).

TABLE L5. COTTONWOOD PASS
1978, via Miramar, Julian, Salton City, and Mecca (3)

Route	Source	Dates of Leveling	Junction bench marks	Observed elevation difference (m)	Orthometric correction (m)
San Diego area	USC & GS quad 321171, line 117	--	LMSL - M57	+5.8830	0.0000
San Diego - Miramar	L-24301.1	1-5/1978	M57 - M1305	+129.4584	+0.0015
Miramar - Julian	L-24301.18	1-5/1978	M1305 - 4219T	+1151.1644	+.1599
Julian - Salton City - Mecca	L-24301.19	1-4/1978	4219T - G516r	+1343.6187	-.1293
Mecca - Cot. P.	L-24301.23	1-4/1978	G516r - D723	+599.7839	+.0320
Cot. P. area	L-23315	3-5/1974	D723 - 2H	-15.8986	-.0058
			Sum =	+526.7724	+0.0583
	Orthometrically corrected height for 2H =			+526.8307 m	