UNITED STATES
DEPARTMENT OF THE INTERIOR
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MEASURED CRUSTAL DEFORMATION IN IMPERIAL VALLEY, CALIFORNIA

Open-File Report 78-910.

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ABSTRACT

Precise geodetic surveys since 1972 indicate that significant vertical deformation of the land surface continues in Imperial Valley, California. Measured vertical changes as great as 3.5 cm per year indicate that two types of tectonic movement are occurring: (1) a downward regional tilt of the valley surface from the Mexican border northward toward Salton Sea, and (2) a deepening of the structural trough presently occupied by Salton Sea. A comparison of 1972-77 change contours with 1927 topographic contours shows gross parallelism, suggesting that the recent deformation is a continuation of the tectonism that formed the Salton trough. Ground movement since 1972 has tended to steepen slightly the gradients of streams, canals, and drains on the valley floor and to increase the capacity of Salton Sea. A usable record of eight years of background measurements of tectonic change are available prior to the impact of geothermal production in Imperial Valley.

INTRODUCTION

Imperial Valley is part of a deep, sediment-filled structural trough on the border between the continental block of western United States and the oceanic block of the eastern Pacific. Major and minor faults, largely masked by young alluvium (Dutcher, Hardt, and Moyle, 1972), traverse the relatively flat valley surface. Currently, this is one of the most tectonically active areas of the country. Within the valley, at least four known geothermal resource areas (fig. 1) are being considered for electric-power generation. Present contracts schedule geothermal production in three scattered areas within 2 years.

One of the potential hazards of geothermal production in Imperial Valley is the threat of induced land subsidence and crustal deformation (Lofgren, 1973). Survey networks of precise vertical and horizontal control have been monitored since 1972 to detect possible crustal deformation prior to geothermal production, and thereby establish background rates of tectonic movement prior to the impact of induced changes (Lofgren, 1974). This report consists essentially of three maps of measured vertical changes in the land surface based on 5 years of leveling control as part of the Imperial Valley geothermal subsidence detection program coordinated by Imperial County. All leveling in this interpretive study was by the National Geodetic Survey, Imperial County, the Imperial Irrigation District, and the U.S. Bureau of Reclamation. Funds for the leveling were provided by numerous private and government organizations.

Three epochs of leveling control are the basis for the maps in this report, (1) October 1971-February 1972, (2) November 1973-May 1974, and (3) November 1976-April 1977. All changes are based on a free adjustment of field survey data by the National Geodetic Survey. This entails the holding of only one bench mark in the network as an assumed-stable reference. In this study, bench mark Y58, 50 km southwest of El Centro, shows zero change; all other marks show their relative movement with respect to bench mark Y58. Free-adjustment elevations for all bench marks in the network for each of the three epochs of leveling were computed by the National Geodetic Survey; reference tabulations are in the files of the Geological Survey and the Imperial County surveyor's office.

Only vertical changes are considered in this report. No attempt is made here to report or interpret the small rates of horizontal ground movement being measured as part of this geothermal research investigation.

MEASURED CHANGES

Figure 1 shows the network of first-order and second-order leveling, geothermal areas (anomalies), and principal canals in Imperial Valley, and also the contours of relative change in land-surface elevation for the 2-year period 1972-74. Changes are with respect to bench mark Y58 and considerably outside of the structural trough southwest of El Centro. Although change contours are quite irregular, and numerous isolated closed-contoured areas appear, the general trend of change was a quite uniform down-to-the-north tilt of the land surface toward Salton Sea. The rate of change in elevation was about 3 cm per year in the 70 km between the Mexican border and the Sea.

Measured changes in land-surface elevation for the 3-year period 1974-77 are shown in figure 2. Change contours during this period reflect two distinct types of deformation, (1) a downward tilt toward the north of about 3 cm per year, and (2) an apparent deepening of the structural trough. Significantly, the shapes of the -2-cm and -4-cm change contours define a deforming trough extending considerably south of the Mexican border. It is also noteworthy that the control mark in bedrock terrain in the southeast corner of the mapped area showed only 2 cm of change during this 3-year period.

Figure 3 shows the combined changes of figures 1 and 2 spanning the years from 1972 to 1977, and also the generalized 1927 topographic contours of the valley floor. This longer base of reference gives a more reliable picture of the complex and rapid tectonic deformation occurring at depth beneath the camouflaging, relatively flat, valley floor. Change contours for this 5-year period clearly reflect the same patterns of vertical tectonic deformation, (1) the down-to-the-north tilt of about 3 cm per year from the Mexican border to Salton Sea, and (2) the marked deepening of the structural trough presently occupied by Salton Sea. Of particular interest is the close parallelism between the 1972-77 change contours, the 1927 topographic contours of the valley trough, and the present shoreline of the Sea (fig. 3). One gets the strong impression that changes of the past 5 years are a continuation of the same tectonic processes that formed the Salton trough during past millennia. Even the northeast-trending transverse fault system south of Brawley that was so active during the January 1975 earthquake swarm (Johnson and Hadley, 1976) is reflected in the change contours of 1972-77.

CONCLUSIONS

(1) Significant tectonic deformation continues on the floor of the Imperial Valley structural trough. The configuration and rates of vertical changes are in apparent harmony with tectonic trends that have persisted through past millennia. Most of the deformation is apparently aseismic.

(2) Measured ground movement from 1972 to 1977 indicates a relative deepening of the structural trough, with the cropland at the southern shoreline of the Sea sinking about 3.5 cm per year with respect to bench mark Y58 outside of the trough. This crustal deformation has tended, in general, to steepen the gradient of streams, canals, and drains, and to increase the storage of the Salton Sea. Not all of the inundation of croplands at the south end of the Sea is due to rising water in the Sea; some is due to the sinking of the land surface--at rates as great as 4 cm per year.

(3) Because geothermal production and ground-water developments to date are minimal in Imperial Valley, all measured 1972-77 changes are attributed to tectonism.

(4) The possible loading effect of water and sediment in the Salton trough since the turn of the century on observed sinking of the trough should be investigated. Reservoir loading frequently causes a downwarping of crust, due to the stresses imposed on the underlying basement. It is entirely possible that part of the tectonic change measured by the 1972-77 leveling is related to the loading of imported irrigation water and the filling of the Sea. There is no evidence of any other type of man-induced subsidence in the valley.

(5) In order to differentiate natural tectonism from induced changes caused by geothermal developments, it is essential that the collection of geodetic data be continued as geothermal developments progress.

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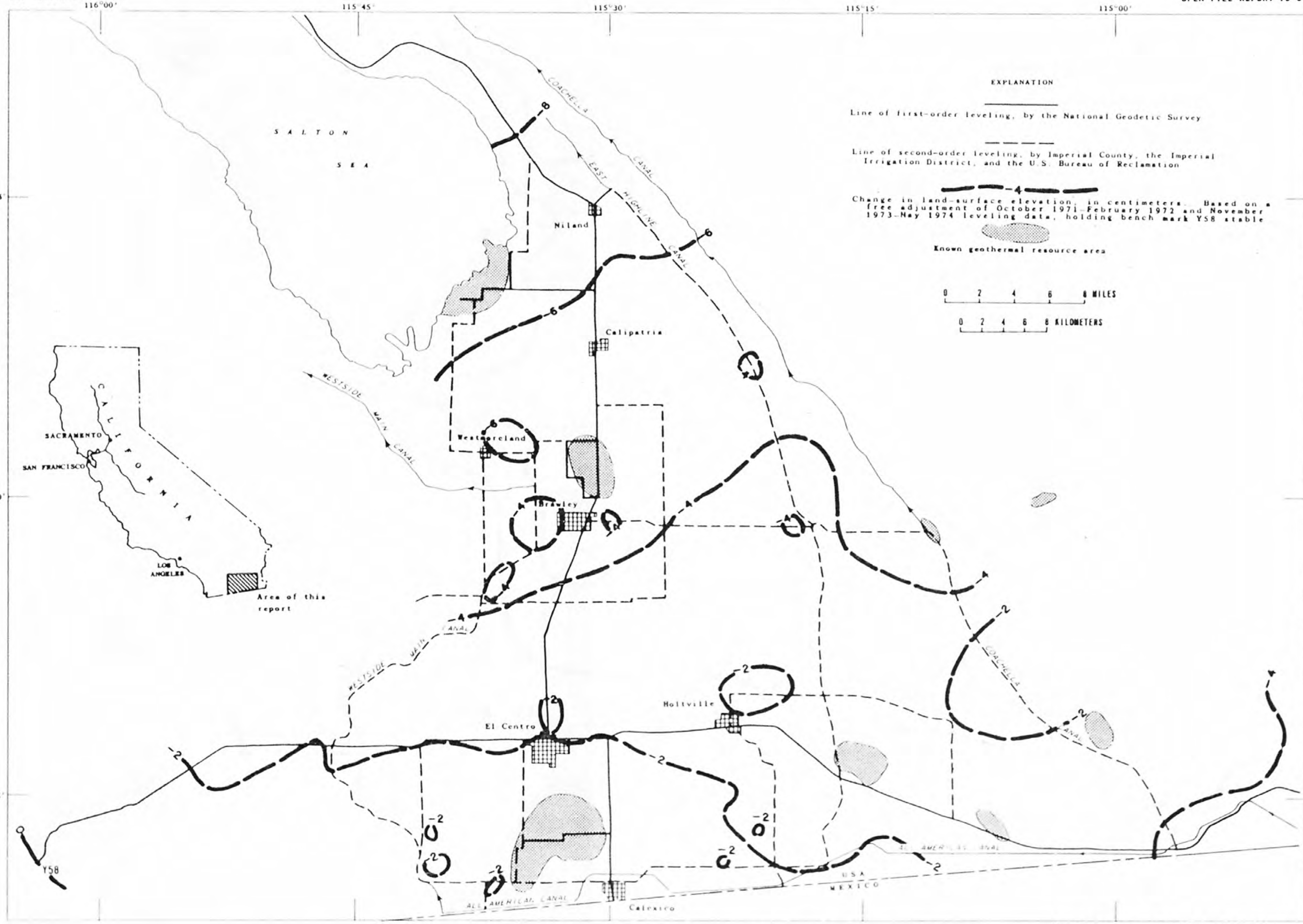

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Figure 1.--MEASURED CHANGE IN LAND-SURFACE ELEVATION, 1972-74, IMPERIAL VALLEY, CALIFORNIA

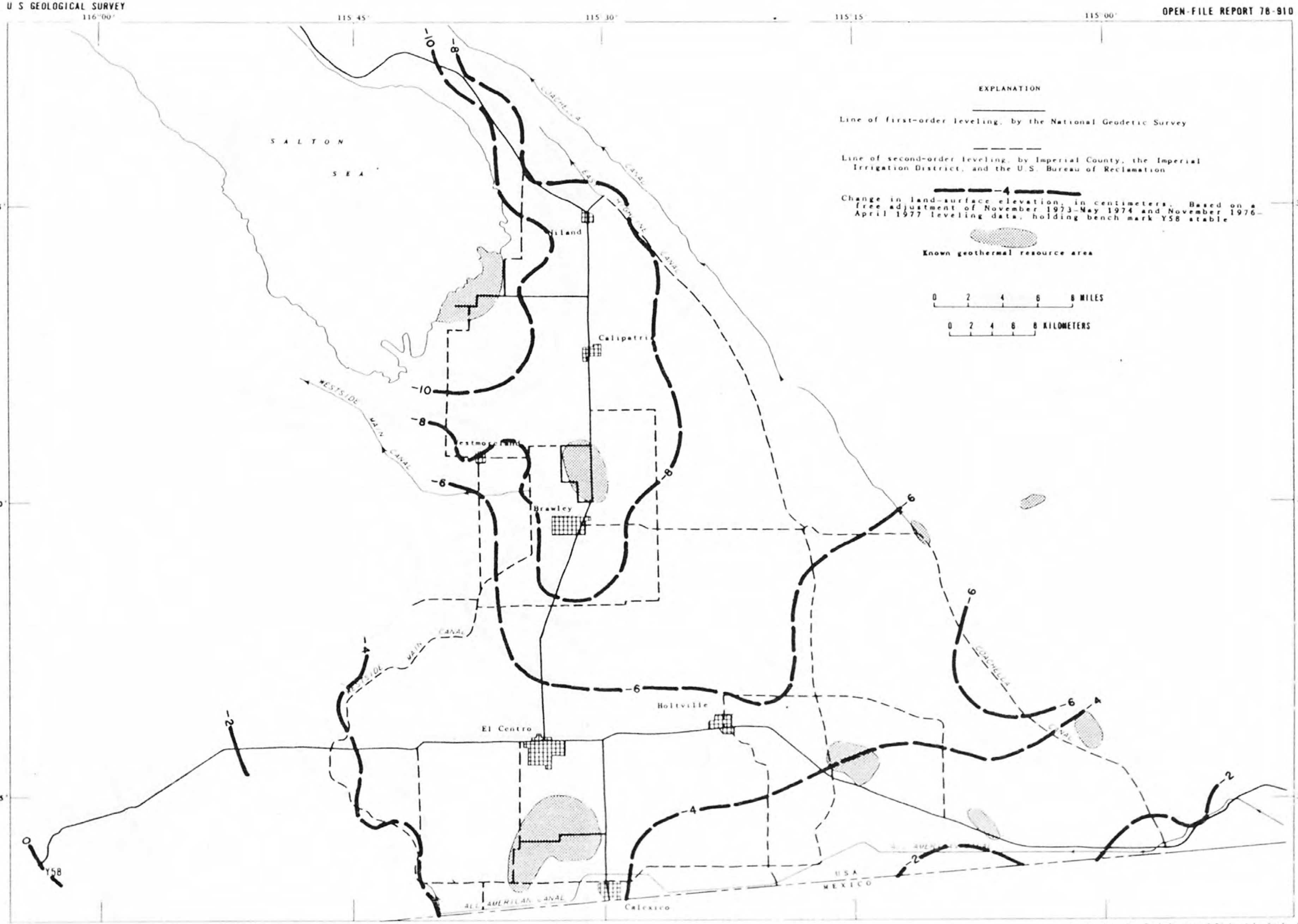

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Figure 2.--MEASURED CHANGE IN LAND-SURFACE ELEVATION, 1974-77, IMPERIAL VALLEY, CALIFORNIA

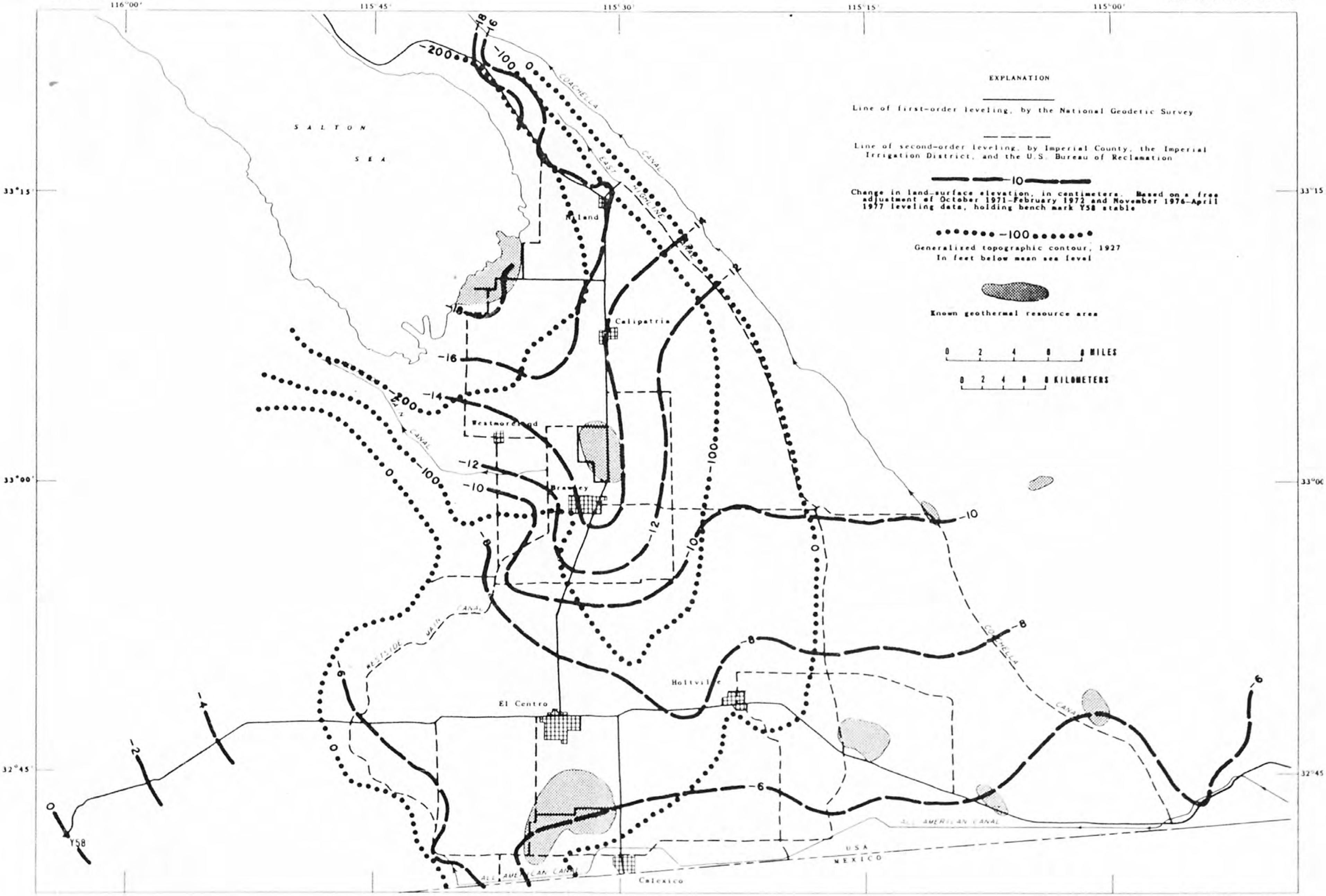

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Figure 3.—MEASURED CHANGE IN LAND-SURFACE ELEVATION, 1972-77, IMPERIAL VALLEY, CALIFORNIA