DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

MISCELLANEOUS FIELD STUDIES
MAP MF—1920

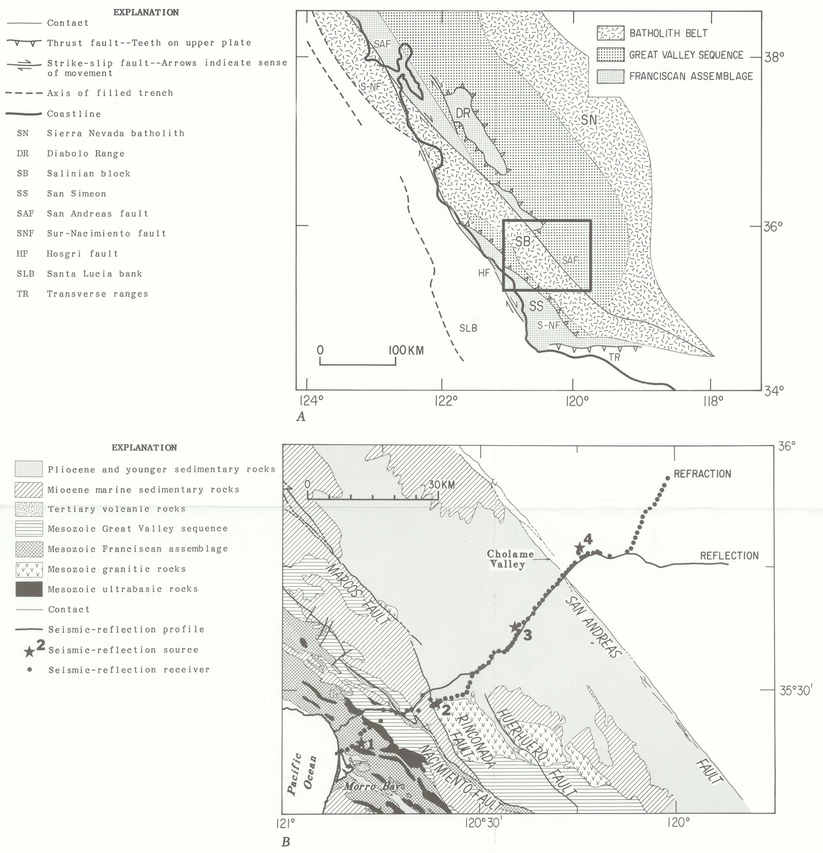

Figure 1.—*A*, Schematic geologic map of central California showing the distribution of terranes and other geologic features in central California (adapted from Page, 1981). The box outlines the area of figure 1*B*. *B*, Simplified geologic map of central California west of the San Andreas fault, showing the location of the seismic-reflection profile, and the sources and receivers for the seismic-refraction profile

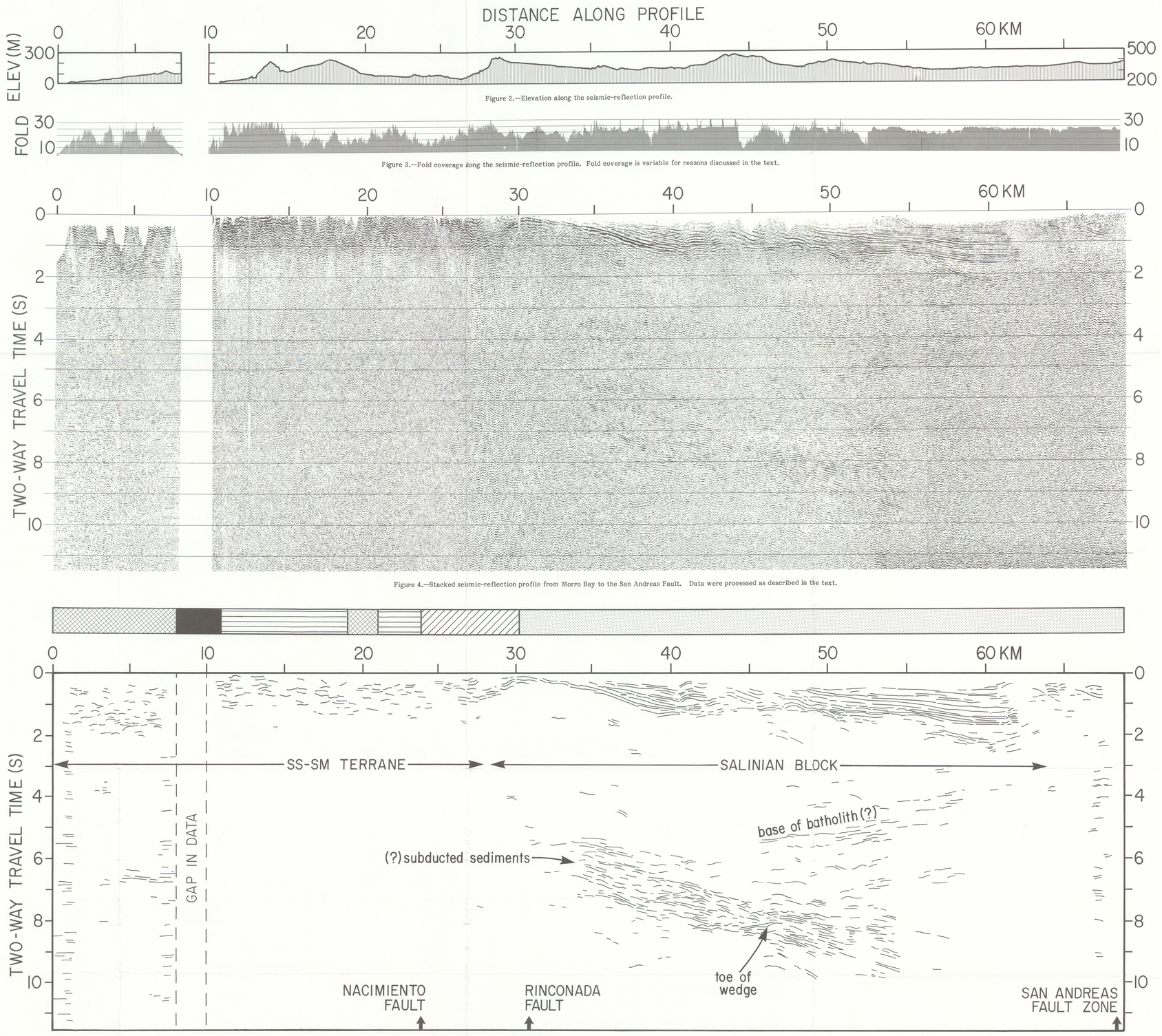

Figure 2.—Elevation along the seismic-reflection profile.

Figure 3.—Fold coverage along the seismic-reflection profile. Fold coverage is variable for reasons discussed in the text.

Figure 4.—Stacked seismic-reflection profile from Morro Bay to the San Andreas Fault. Data were processed as described in the text.

Figure 5.—Annotated line drawing of the seismic-reflection profile shown in figure 4 and bar graph of the surface geology (see figure 1B for explanation of patterns).

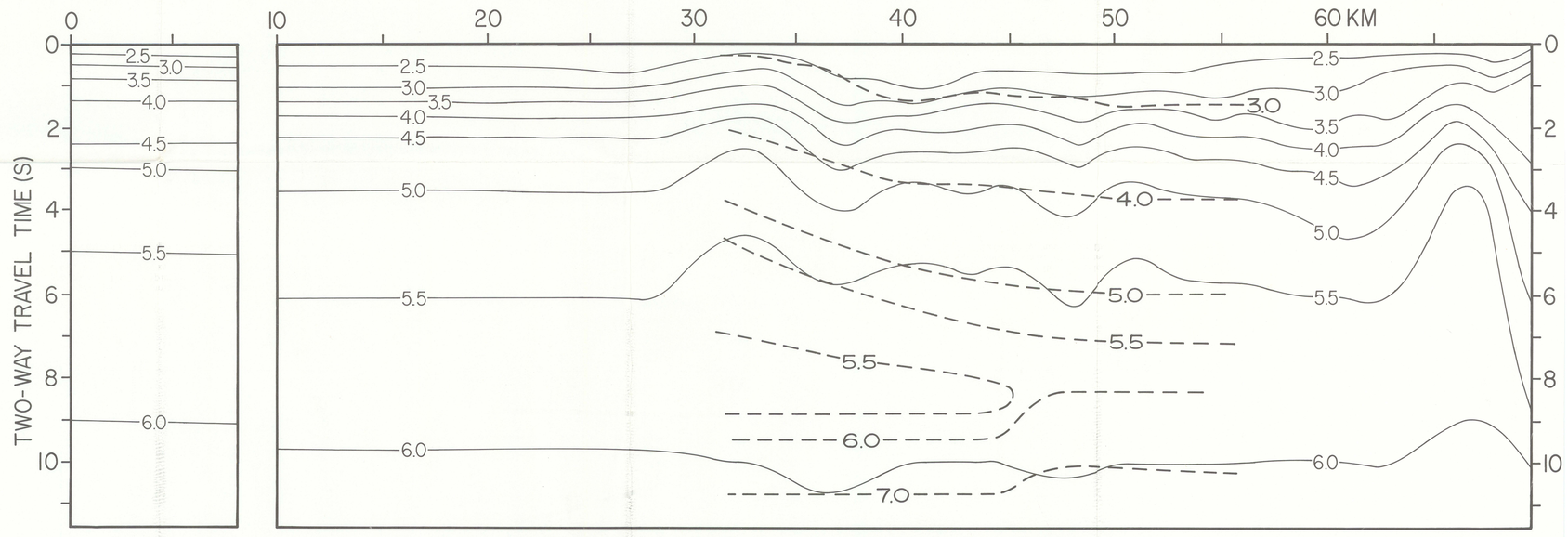

Figure 6.—Root-mean-squared velocity model used for normal-moveout correction of CDP data (solid contours), and interval velocity model used for migration of stacked data (dashed contours). Numbers are in units of km/s.

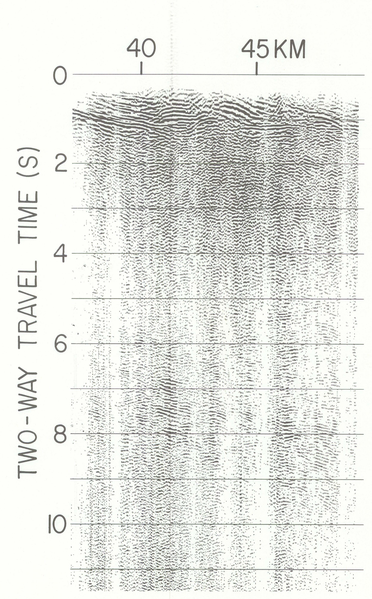

Figure 7.—Example of seisnic data to which no AGC has been applied. True amplitude relationships are therefore preserved. In addition to the spherical divergence correction, an exponential gain was applied from 3 to 12 s with the gain at 7.5 s relative to 3 s being 6 decibels.

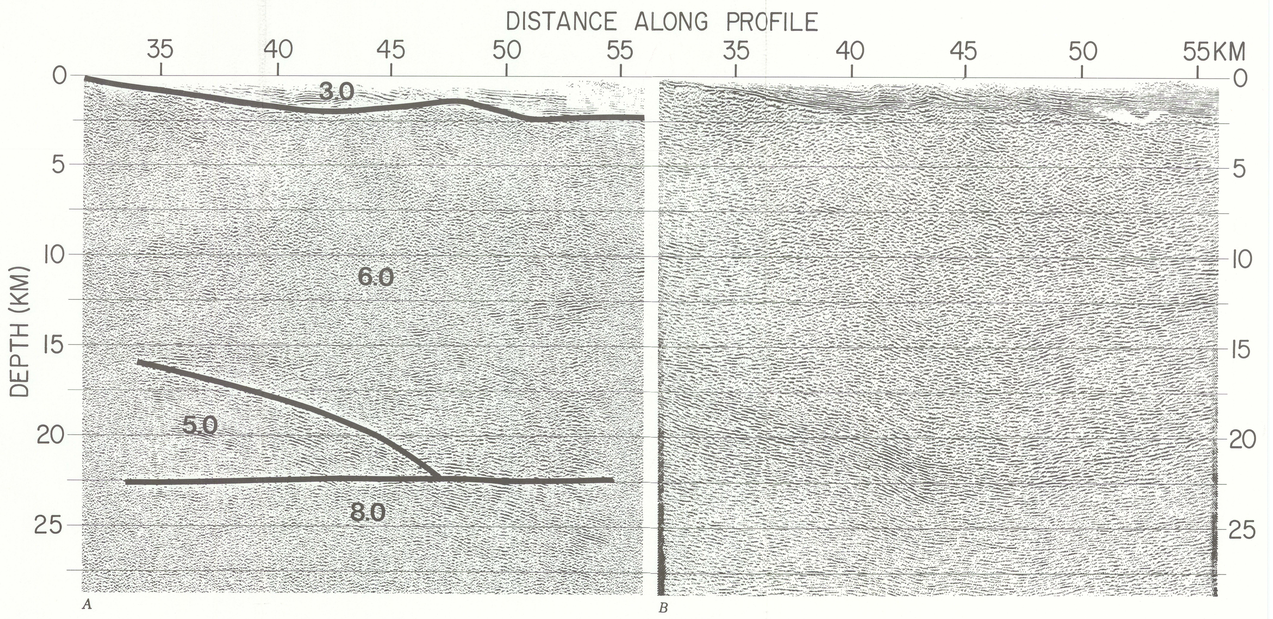

Figure 8.—*A*, Depth section of a part of the seismic-reflection profile. The velocity model for calculating the depth section is superimposed. Numbers are in units of km/s. *B*, Migrated depth section. The velocity model shown by dashed contours in figure 6 was used for migration; the migrated time section was converted to depth using the same model as in *A*.

SEISMIC REFLECTION PROFILE ACROSS THE COAST RANGES OF CENTRAL CALIFORNIA–MORRO BAY TO THE SAN ANDREAS FAULT

By
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1987

INTRODUCTION

Seismic-reflection data from the Coast Ranges of central California were reprocessed to extend the original 6-second (s) long record to 14 s. The seismic profile extends across the Coast Ranges of central California from the Pacific Coast near Morro Bay to the San Andreas fault near Cholame (figures 1*A*,*B*). The eastward continuation of the profile, from the San Andreas fault to the foothills of the Sierra Nevada, has been studied by others and will not be discussed here (Wentworth and others, 1983). A comprehensive review of the geology of this region has been presented by Page (1981) and is summarized in figures 1*A* and 1*B*. The western part of the profile is underlain by Mesozoic rocks of the Franciscan assemblage, locally overlain by pockets of Jurassic ophiolite and Mesozoic sedimentary rocks of the Great Valley sequence. We will refer to these rocks as the San Simeon (Franciscan assemblage)-Stanley Mountain (ophiolite and Great Valley sequence) composite terrane, as suggested by Champion and others (1984). To the east of the San Simeon-Stanley Mountain composite terrane and separated from it by the Nacimiento and Rinconada fault zones is the Salinian block, a crystalline terrane containing closely spaced Cretaceous granitic plutons similar in age and composition to the rocks of the Sierra Nevada batholith belt. Along the profile discussed here, the Salinian basement rocks are overlain by a sequence of Miocene and younger sedimentary rocks.

A primary motivation for reprocessing this data was to test whether a low-velocity zone in the lower crust, inferred to exist on the basis of large-offset data shot coincident with the reflection profile (Murphy and Walter, 1984; Trehu and Wheeler, 1987), could be detected in the reflection data. In the large-offset data, a large-amplitude, late arrival observed at ranges of 40-60 km can be interpreted to be a wide-angle reflection from the base of a low-velocity zone having a vertical intercept time of about 8-10 s two-way travel time.

DATA ACQUISITION AND PROCESSING

The reflection data were shot and originally processed by Western Geophysical Co. in 1981 and reprocessed by us at the U.S. Geological Survey (USGS) using the Digicon* DISCO seismic processing programs. A 48-channel, split-spread geometry was used with a station spacing of 67 meters (m) and an initial source-receiver offset of 268 m; this yielded nominal 24-fold coverage with a maximum offset of 1,811 m. Because most of the profile was shot along winding mountain roads (fig. 1*A* and 2), we defined a smoothed common depth point (CDP) line with a CDP spacing of 34 m and only accepted source receiver pairs for which the bottoming point fell within a 17-x-100-m box around the CDP; consequently, the actual fold coverage is quite variable (fig. 3).

Twenty-six seconds of data were recorded from a 20-s Vibroseis sweep containing frequencies ranging from 10 to 52 Hz, yielding a 6-s record. At each station, 10-12 sweeps from 4-6 trucks were summed. The data were recorded in SEGC format (set by the Society of Exploration Geophysicists) with a sampling rate of 4 ms. Because the data were collected with an upsweep (a sweep in which frequency increases with time), it was possible to append 8 s of zeros to the end of the field data and recorrelate the augmented data set to yield a 14-s record, a method described by Okaya (1986). With this method, the high frequencies in the source are progressively lost below 6 s in the correlated data. Because of the long field sweep used in this experiment, a source frequency band of 10-40 Hz remains at a time of 14 s in the recorrelated data. We consider this to be an adequate bandwidth for studying the lower crust because the observed lower crustal reflections in the Vibroseis data contain primarily 10- to 20-Hz energy.

In order to minimize the effect of spurious noise sources, such as passing vehicles, an AGC (automatic gain control) that had a window length of 3 s was applied to the data before correlation with the sweep. This also has the effect of whitening the background noise in the correlated data (Coruh and Costain, 1983). A sample of data was also processed without applying an AGC before correlation in order to preserve amplitude information.

After correlation, the data were sorted and resampled at an 8 ms sampling rate. Static corrections were applied to normalize the traces to a datum of 300 m, the average elevation of the profile. Surface-consistant residual statics were also calculated for the portion of the profile overlain by a Miocene to Holocene sedimentary basin. The strong reflector at the base of the basin was used as a reference. This greatly increased the continuity of reflectors within the basin, but had little effect on the deeper reflectors. A spherical divergence correction was applied to compensate for the effect of spherical spreading, and the data were pass-band filtered with a pass band of 5-50 Hz from 0-2 s and 5-30 Hz from 4-14 s (with a linear interpolation of the two filters from 2-4 s). Experiments with deconvolution operators did not produce a noticeable improvement in the data; therefore, no deconvolution was applied for the final section.

Velocities for the normal moveout correction were determined for the upper 3-4 s from visual observation of the moveout obtained from a series of velocity functions. For the deeper structure, and in places where no clear shallow reflectors could be observed, velocities suggested by the refraction data were used. Because of the small maximum offset, the reflection data are insensitive to velocity uncertainties in the lower crust.

After normal moveout, the data were muted and stacked. The stacked data were pass-band filtered (5-30 Hz) and an AGC with a window length of 3 s was applied. Selected portions of the data were migrated using a finite-difference algorithm. Both the unmigrated and migrated sections were converted to depth using a velocity model derived from both the refraction and reflection data.

DATA INTERPRETATION

Figure 4 shows the first 11.5 s of the full seismic section. No reflections were observed below 11.5 s. A line drawing interpretation is shown in figure 5. The stacking velocities are shown by the solid contours in figure 6. No continuous reflectors are observed beneath the region where Franciscan rocks are exposed on the surface (km 0 to km 25) but a band of discontinuous reflections is observed between 1 and 2 s. Unstacked shot and CDP gathers show that in this region most of the energy is refracted in the near-surface because of a very strong near-surface velocity gradient. Reflectors showing normal moveout can be observed in both CDP and shot gathers, but they are not continuous for more than a few CDP gathers. The energy is probably being scattered by irregular blocks within the Franciscan melange with dimensions on the order of tens of meters. No deep reflections are seen beneath this region, probably at least in part due to the scattering and refraction of energy in the near surface.

Farther to the east, the sedimentary basin overlying the Salinian block is well defined. The sedimentary rocks thicken to the east to a maximum of nearly 2 s (approximately 3 km) and show both faulting (near km 41) and infilling (near km 52) of an irregular basement surface. A band of westward-dipping reflection is observed at about 4-10 s beneath the eastern part of the Salinian block (km 45-60). These reflections are similar to reflections observed in several other reflection profiles across granitic batholiths and interpreted to represent the base of the batholith (Lynn and others, 1981).

Most interesting are the eastward-dipping reflections observed beneath the Salinian block between 4 and 10 s and km 30-60. The strength of these reflections is illustrated in figure 7, in which amplitudes have been corrected only for spherical spreading and no AGC has been applied. Note the wedge-shaped structure at about 8 s beneath km 45-50. These reflections terminate abruptly just to the east of the Rinconada fault. We suspect that this indicates a difference in the propagation characteristics of the shallow crust between the San Simeon-Stanley Mountain terrane and Salinian block rather than the absence of deep reflections. The termination of the deep reflections corresponds to a sharp increase in the low-frequency background noise level, and the change in noise level corresponds to a new day in the field; we therefore conclude that the absence of deep reflections in this region is due to a change in environmental conditions. This interpretation is supported by the absence of hyperbola of diffracted energy, which would be expected if a sharp reflector ended abruptly, and by the large-offset data (Trehu and Wheeler, 1987), which require that a low-velocity zone extend beneath both the San Simeon-Stanley Mountain terrane and the Salinian block. The deep reflections also terminate abruptly to the east as the San Andreas fault zone is approached. No continuous reflections are observed beneath the San Andreas fault zone.

Figures 8*A* and *B* show a depth section and a migrated depth section of the central portion of the profile. The migrated section was obtained by migrating the data in the time domain using a finite-difference routine and then converting the migrated time section into depth. The velocity model used for migration is shown by the dashed contours in figure 6. The low-velocity zone shown in the model is based on results from the large-offset data (Trehu and Wheeler, 1987). The migration is quite robust with respect to changes in the velocity model and very similar sections are obtained for constant velocity migrations when velocity is varied from 4.5 to 6.0 km/s. The east-dipping reflections at 4-10 s correspond to a structure with a dip of approximately 20 degrees at a depth of 16-24 km between km 32 and km 45. East of km 45, the deep reflectors are either flat or slightly westward dipping.

DISCUSSION

Interpreting these reflection data in conjunction with large-offset data, we suggest that the eastward-dipping reflections at 16-24 km correspond to the low-velocity zone inferred from the large-offset data. This implies the presence of sedimentary material beneath the coast ranges of central California. Details of this interpretation have been discussed by Trehu and Wheeler (1987). Although a low-velocity zone has been inferred to exist in the lower crust beneath several regions in central California on the basis of large offset data (Blumling and Prodehl, 1983; Blumling and others, 1985), the data displayed here represent the first observation in coincident reflection data of a laminated structure at a corresponding depth. The eastward dip of the structure observed in this reflection data suggests that the sedimentary wedge was subducted beneath a now inactive trench offshore to the west. Additional reflection and large-offset data from the offshore region are needed to test this hypothesis.

ACKNOWLEDGMENTS

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* The use of trade names is for descriptive purposes only and does not constitute endorsement by the U.S. Geological Survey.

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