Given the sparse construction in the affected area, the scarcity of reliable witnesses and the high concentration of damage related to adverse soil behavior, no attempt was made to define isoseismals or intensity for this earthquake.

7. Surface Ruptures Observed at Ejido Saltillo, Baja California after the Mexicali Valley Earthquake of 9 June, 1980

R.V. Sharp

Following the 9 June 1980 earthquake near Victoria, Baja California, J. J. Lienkaemper and I briefly investigated the Imperial fault in California to determine whether a new pulse of after slip of the 15 October 1979 earthquake might have been triggered by the new seismic event. On June 12, we checked the Imperial fault in Mexico for evidence of new displacement, as well as several locations along the Cerro Prieto fault in the epicentral region (Figure 7.1). On returning by way of Ejido Saltillo, our car reported a vertical offset in the pavement of Pascualitos—Pescaderos highway with a provocative jolt. The local farmers' knowledge of new ruptures greatly expedited our subsequent observations, which are briefly summarized here.

The observations and measurements of displacement were made in the field without benefit of detailed maps or aerial photographs. Several days later, I reconstructed the traces of new rupture on aerial photographs from memory and photographs taken in the field. These traces are shown in Figure 7.2. Although some of the breaks are located precisely with respect to road intersections, etc., many may be only within several tens of meters of their actual positions.

Description of surface fractures. The fractures at Ejido Saltillo broke the ground surface discontinuously along a north-northwest-trending zone for at least a kilometer near the west side of the settlement. At the southeast end of the zone where they were best developed, and at the highway, the fractures grouped in the left-stepping en echelon pattern that is characteristic of right-lateral surface faulting. At other locations, the en echelon pattern was not obvious, and at some places the principal component of displacement appeared to be vertical rather than horizontal.

Locality A: The surface fractures at this location were pristine on June 12, and they showed the greatest displacement that we found. The breaks consisted of an en echelon series of slightly gaping fissures oriented about north-south, and the zone of breaks trended about 10°—15° west or north (Figure 7.3). Pre-earthquake harrow-disc grooves in this field provided reference marks from which the displacement could be determined accurately; at A the largest component of slip, 16.5cm, was right lateral in sense, and the vertical component, up on the west, was 10cm. At most other places in this field, the horizontal component was much less and the vertical component appeared to be nearly zero.

The breaks died out southward within this field but we did not determine their extent accurately. We checked the north levee of Canal Delta Numero Uno and found no rupture. If other undiscovered breaks occurred closer to the epicenter, they were not continuous with those in this field.

Locality B: This location is at the only concrete-lined canal in the zone of surface breaks. The canal showed evidence of slight buckling, and we judged that the side east of the buckle may have raised slightly. The canal remained straight, so that horizontal slip here was apparently absent. There was a small hairline extensional crack crossing the east levee about normal to its length. This crack may have been caused by shaking rather than displacement of the ground.

Locality C: A line of surface cracks here was observed by residents after the earthquake, but they were not visible at the time of our inspection. Although billowing dust raised by traffic passing on the adjacent dirt road accounted for obliteration of narrow cracks, we detected no obvious sign of vertical displacement of the dust-covered ground surface that would have been more difficult to obscure.

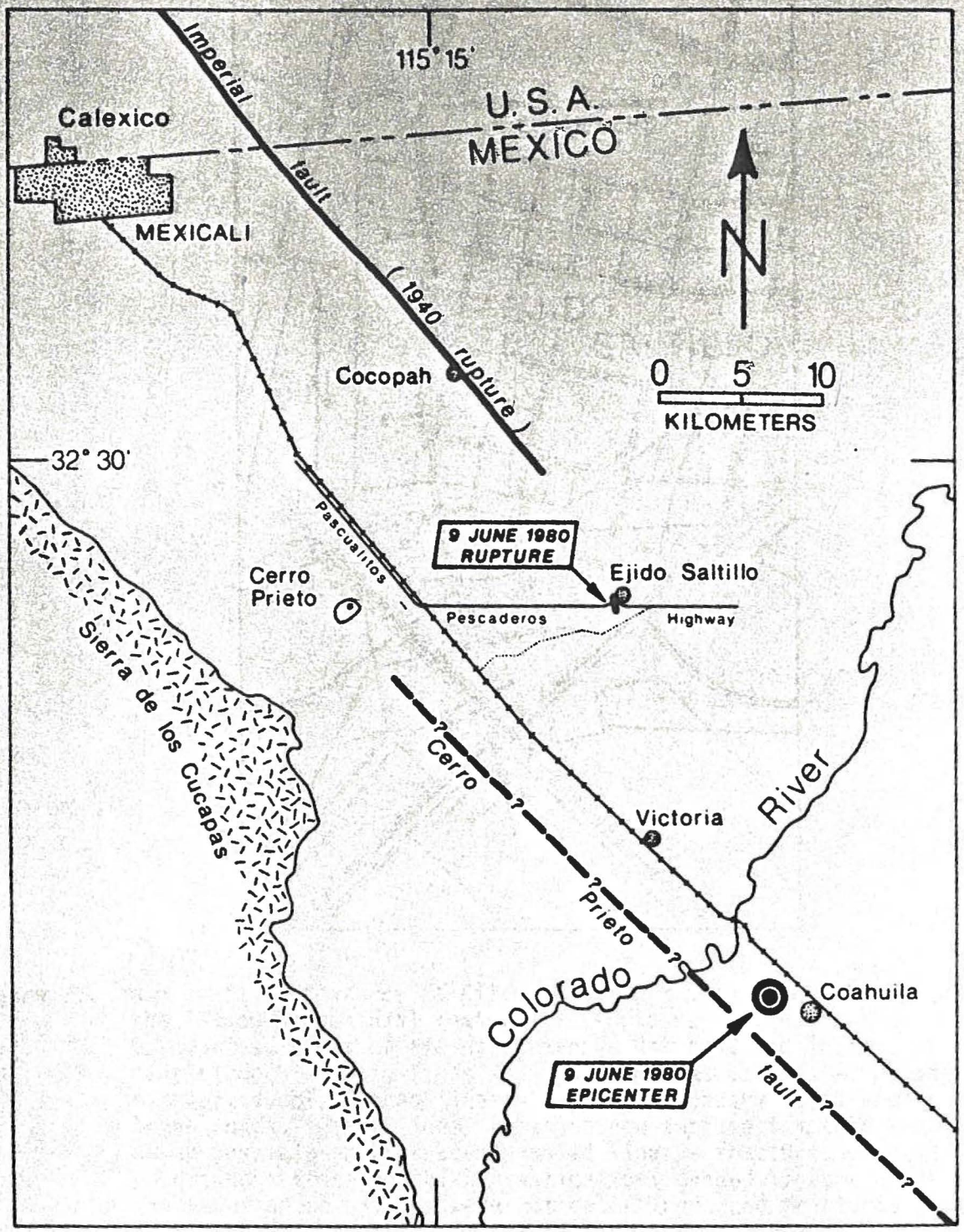

Figure 7.1. Regional map showing the epicenter of the 1980 Victoria earthquake, surface ruptures at Ejido Saltillo, and the traces of the Imperial and Cerro Prieto faults. Dotted line represents Canal Delta Numero Uno.

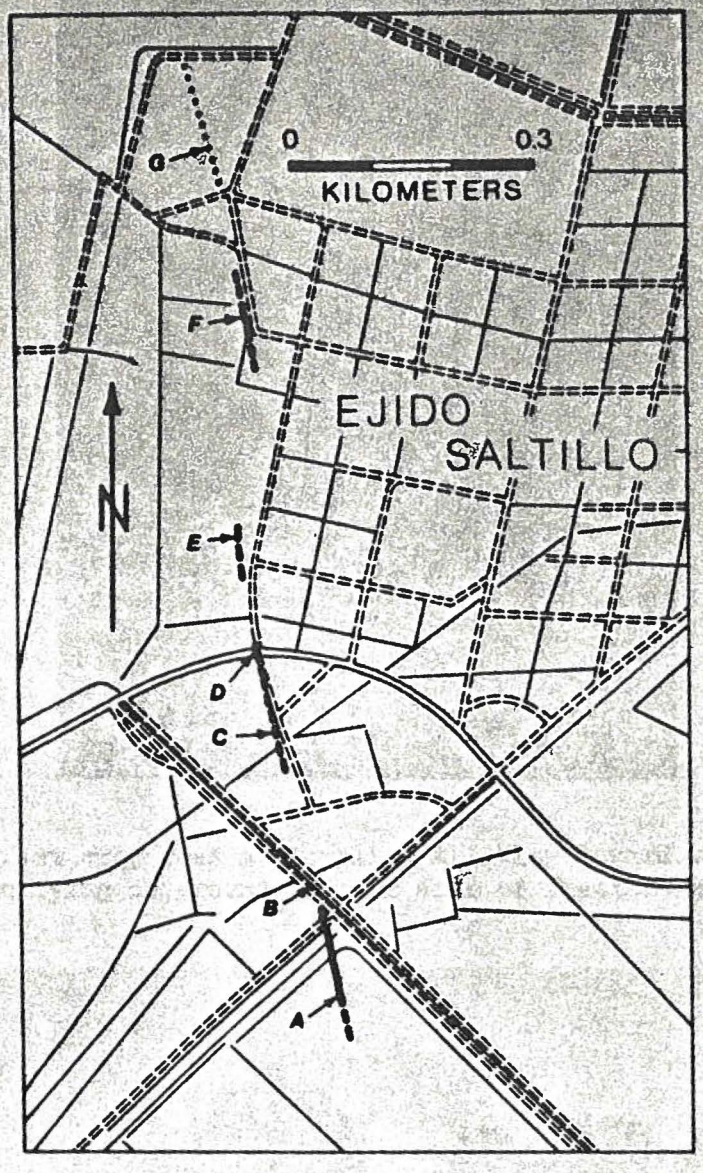

Figure 7.2 Map of fault features at Ejido Saltillo. Light lines indicate the following cultural features: single solid lines - land Boundaries, edges of fields, drainage ditches, and irrigation canals; double solid lines - pavement of Pascualitos - Pescaderos highway; double dashed lines - unpaved secondary roads and levee roads. Heavy lines represent new surface fractures and other possible fault traces: solid lines - fractures observed on ground surface in this investigation; dashed lines - observed fractures whose extents were not determined, and fractures that were observed by residents but were obliterated before our investigation; dotted line - pronounced lineament in cultivated field that is visible on aerial photographs. Letters at arrows indicate localities discussed in the text.

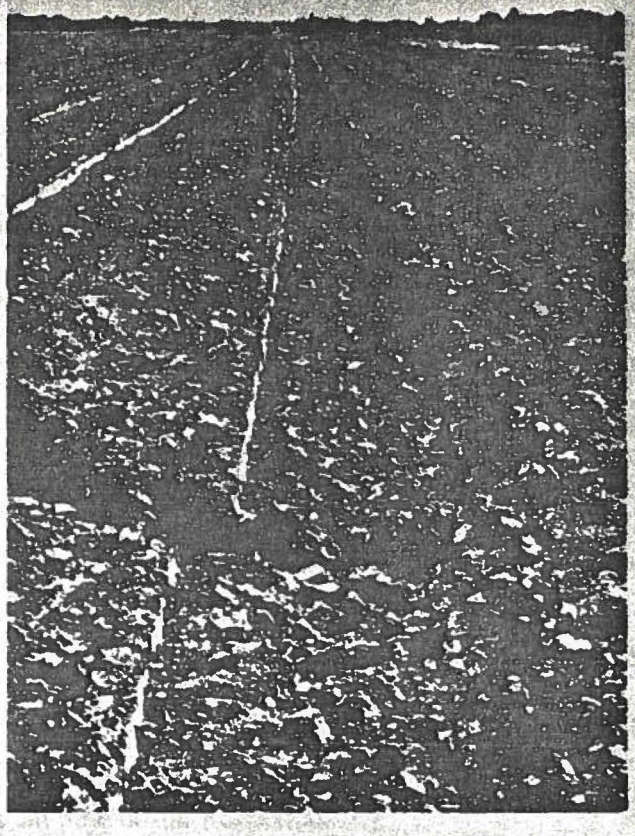

Figure 7.3 Offset crop rows at locality A. View toward west-southwest. Pen lying on ground on near side of fracture gives scale.

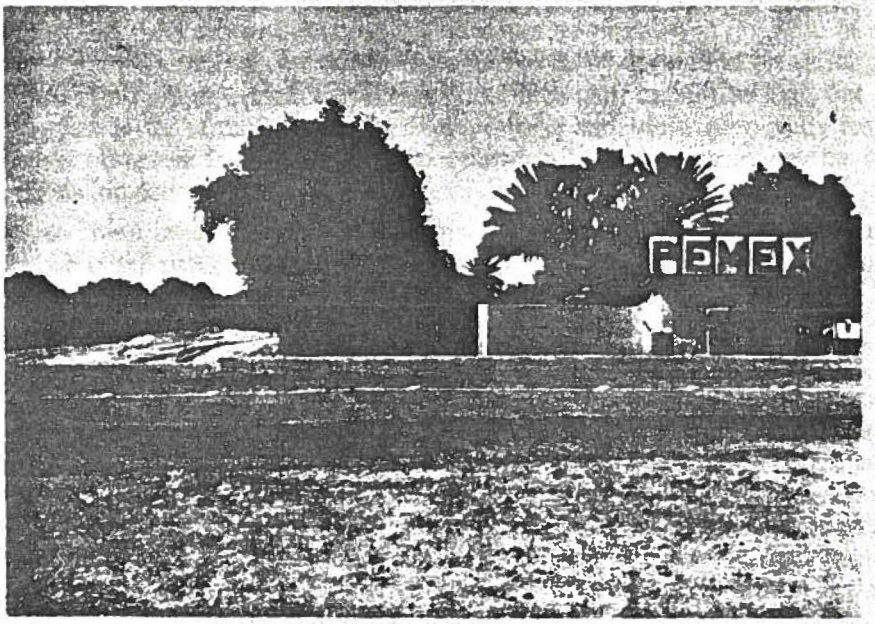

Figure 7.4 En echelon fractures and vertical deformation at locality D. View is toward north.

Locality D: The pavement of Pascualitos—Pescaderos highway was broken by a set of left-stepping en echelon fractures (Figure 7.4) that coincided with the crest of a zone of vertical displacement at least 2 meters wide. Although the fractures appeared to be relatively fresh, it is possible that new movement enlarged preexisting fractures. The sense of the vertical displacement was down to the west, and the painted line showed no obvious horizontal shift. The profile of deformation and the position and pattern of the cracks was similar to that observed at the Brawley fault zone that broke in the Imperial Valley in 1975 and 1979.

Neither cracks nor vertical displacement could be detected on the dirt shoulders of the pavement, thus casting doubt on the significance of the deformation in the pavement. However, the location of the break in the pavement is exactly at the intersection of dirt roads converging from the north and south. The volume of traffic over these dirt roads and on the shoulders of the highway was sufficient to have erased fractures in the three days before our visit, but not so for the obliteration of vertical relief comparable to that in the pavement. I conclude that most of the vertical deformation occurred at unknown times before the Victoria earthquake and that vertical and horizontal components of new slip must have been either very small or broadly distributed.

Locality E: Among the myriad desiccation cracks that pervaded this periodically irrigated field, at least one crack among them showed relatively greater width (1—2cm) and vertical displacement across it (~ 1cm down to the west). The crack was oriented a few degrees west of north and was located at the eastern crest of a slight downwarp visible in the grade of the crop rows. The rows were not offset horizontally. The overall appearance of these features was similar to that seen in some fields crossed by strands of the Brawley fault zone after the 1979 Imperial Valley earthquake. No attempt was made to trace this feature across the field, so I cannot place limits on its full extent here. However, it was not visibly continuous with the break at locality D at the time of our inspection.

Locality F: A narrow zone of minutely gaping extensional cracks formed along a row of trees bordering the dirt road at this locality. No evidence of vertical or horizontal shift was detected on these breaks. Although they were not traced to the north and south, the next road that crossed the projection of these fractures about 100m farther north showed no obvious sign of new disturbance.

Locality G: This field was not checked for new rupture because at the time of our visit we were unaware of the pronounced contrast in the appearance of vegetation on aerial photographs of this field. I have no direct evidence that this photolineament is fault related, but I show it in Figure 7.2 because of its remarkably suggestive position and orientation with respect to the breaks that were observed farther south. No other photolineaments along the line of new breaks or along its projections were detected.

Discussion. These breaks appear to be primary tectonic features because: (1) no evidence of liquefaction or other secondary breakage of the ground surface was observed around Ejido Saltillo; (2) the left-stepping en echelon pattern of rupture was well developed at localities A and D; and (3) the deformation in the pavement at locality D suggested that movement of a similar kind had occurred before the 1980 Mexicali Valley earthquake.

A fault along these breaks might be related to the Imperial fault whose southernmost documented rupture in the 1940 Imperial Valley earthquake lies about 8km to the northwest. Because field checking of the 1940 rupture south of that point was cursory, there is no definite information on whether additional fault strands at the location of Ejido Saltillo might have been active in 1940. In his book *Elementary Seismology* (p.494), C.F. Richter mentions (without discussion) reports of additional 1940 faulting south of the mapped Imperial fault rupture, as well as north-south cracks visible on 1941 aerial photographs; whether the 1980 breaks at Ejido Saltillo coincide with any of these is unknown at present.

No clearly defined scarp was detected at any location along the new ground ruptures. However, land grading and leveling associated with the agricultural activity and road construction could have completely erased a predevelopment scarp if the relief on it was small. There is

some suggestion in the layout of roads in Ejido Saltillo that the line of new surface breaks might once have been a natural boundary or barrier.

8. A Review of Geological Effects and Damage Distribution of the June 9, 1980 Mexicali Valley Earthquake

F. Suarez V., K.E. Sieh, W.E. Elders

The June 9, 1980 earthquake ($M_L = 6.1$) occurred on the Cerro Prieto fault located in the Mexicali Valley (Figure 8.1). A day and a half after the event, the area was inspected both from the air and on the ground.

The aim of the aerial reconnaissance was to obtain evidence of possible slippage of the Cerro Prieto fault as well as other phenomena related to the earthquake.

We did not observe any tectonic feature which can be related to the Cerro Prieto fault, no fresh scarps or fractures clearly indicating tectonic slip.

We found a lot of damage in the agricultural areas as well as in the small towns and villages located in the valley. The damage increases from the Cerro Prieto volcano (where scattered sandblows and fissures were observed) to the southeast and concentrates around the village of Pescaderos (Figure 8.1) and then decreases south from this point.

The ground reconnaissance started in the Cerro Prieto geothermal field where some fractures and sandblows were found just east of the Geothermal Electrical Plant (photo 1). A geologist from the Coordinadora Ejecutiva de Cerro Prieto finished a structural map of the area around the geothermal field and found three different sets of fractures. One set of fractures is oriented north-south, a second one has a general strike east-west and the third set of fractures has a northeast-southwest orientation. He believes that the northeast-southwest, and the east-west sets are tectonic features. We think that none of these fractures or cracks are tectonic; instead they could be features developed due to a liquefaction process.

The owner of a ranch near the Geothermal Plant told us that the shaking of the ground was from north to south and south to north. If he is right, we can infer that the zone of fractures is a result of a shaking perpendicular to the direction of the fractures and the liquefied layer below came spurting up through the fractures. This effect can be seen in photo No. 2, where a sandblow is emitting cold water and some yellow crust around the crater has formed indicating that some kind of gas was associated with the crater.

The largest fractures seen in this area were found near drains or irrigation canals. These fractures seem to be purely extensional features associated with the canals and also with the shallow liquefied layer. Perhaps, the digging of the canal involved removal of a significant portion of the overlying stiff silt of clay. The failure took place along the weakest part of the overlying stiff material (photo 3). We did not see any major damage to structures moving south of the geothermal field and passing the towns of Delta and Oaxaca. However, immediately upon leaving Oaxaca the road at the southeast of the town had many extensional transverse cracks (photo 4). Some of these cracks showed right lateral movement of about 2cm. Following this main road, we drove for about 5km looking for some evidence of the Cerro Prieto fault. Using seismic evidence alone, (Reyes 1979), this is a place where the fault can be traced, and therefore this should be the site to look for any tectonic features related to the fault; unfortunately, we could not find any of these features.

The general damage increased substantially from Olachea to Pescaderos, besides the damage in the agricultural areas (photo 5); the destruction in Pescaderos was very high. The damage here was definitely more severe than what we observed elsewhere; a quick view shows that 13 out of 39 adobe houses suffered major damage (including complete collapse) and this was also the case of two out of 19 concrete block houses (photos 6,7,8). It was also in this area where the railroad was warped and bridges were affected to the point that the rail traffic was interrupted for several days (photos 9,10).

According to Allen (personal communication) the Cerro Prieto fault can be seen on the surface south of Pescaderos. He describes a low scarp near to an old school within a cotton

VICTORIA 1980 (Saltillo rupture)

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