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Exploratory Trench Across the Pleasant Valley Fault, Nevada

by

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Abstract

An exploratory trench was excavated across the 1915 trace of the Pleasant Valley fault 60 km south of Winnemucca, Nevada, to get information on the history of recent displacements on a fault that had produced a major earthquake in historic time, and on the appearance of such a fault in a trench cut in gravels, sands and silts of an alluvial fan.

The trench exposed 16 mappable sedimentary units and four soils, including three buried paleosols. The ages of the mapped units could not be narrowly defined but they are of late Quaternary age. Some rodent bones suggest a possible age of about 5,000 years for one of the higher stratigraphic units.

The fault zone is very clearly represented in the trench, and, to the full 4-m depth of the trench, consists of a zone of fault rubble as much as 1.5 m wide. Two fractures outside the fault rubble show no vertical displacement. In addition to the fault rubble, the fault is conspicuous because several of the mapped units terminate abruptly against the rubble zone, and because the sediments southeast of the zone are coarser-grained than the sediments northwest of the zone.

Maximum vertical component of the 1915 displacement was estimated to be 0.4-0.6 m based on topography and 0.5-0.6 m based on displacement of stratigraphic units including soils. Two or more episodes of vertical displacement, one of about 0.3 m and another totaling at least 1.15 m prior to 1915 are recorded and may have occurred in the last 5,000 years. These and other displacement events prior to 1915 are poorly dated, but that several did occur in late Pleistocene and Holocene time is certain.

Lack of wedge-shaped deposits or concentrations of large clasts adjacent to the fault suggest that all displacements were produced in small increments of probably less than one meter each.

Introduction

An exploratory trench was excavated across the October 2, 1915, trace of the Pleasant Valley fault 60 km south of Winnemucca, Nevada. This work was part of a broader study, sponsored by the U.S. Nuclear Regulatory Commission, of the use of trenching in evaluating active faults. The principal purpose was to obtain information on the recent history of the fault, and on the fault's appearance in the trench. A suitable site required young bedded sediments, and fault displacements small enough so that young displaced beds on the downthrown side could be reached in a trench about 4 m deep. A site meeting these criteria was found on the Pearce scarp segment of the fault, in the NW 1/4 sec. 35, T30N., R39E., Mt. Diablo Base and Meridian, which is 1.2 km N.41.5°E. of the Siard Ranch house (Fig. 1), where bedded alluvial fan deposits were displaced less than 1 m in 1915 (Wallace, 1980). The site is 3-4 km west of the front of the Tobin Range from which the sediments in the trench were largely derived. Ground surface elevation at the site is about 1620 m; the local topography and the location of the trench can be seen in figure 2. The trench was oriented about N.40°W., perpendicular to the fault, and was about 30 m long, 1 m wide and 2-4 m deep. Trench supports consisted of hydraulic shoring with a spacing of 1.4-1.8 m between sets. The trench was open from September 7 to September 22, 1977.

Mapping of the trench

The southwest wall of the trench was thoroughly cleaned with pick and brush (additional cleaning was needed during mapping, owing to the dry and dusty conditions) and mapping units were selected, primarily on the basis of lithology, soil development, or stratigraphic criteria. The unit boundaries were then identified and marked with spray paint, nails, and flagging. Mapping was done by measuring vertical sections about 1 m apart with supplemental measurements at critical points; horizontal control was by steel tape and vertical control was by line level. The northeast wall was inspected but not mapped because the units and fault features correlate closely across the trench. Cleaning of the walls, and selection, marking and mapping of the units was done in 11 days by H. A. Villalobos and T. A. Kaplan-Henry.

Sedimentary units mapped in the trench

The sedimentary materials exposed in the trench were divided into 16 units. Except for the uppermost unit, which is primarily loess, all of the units are of types characteristic of an alluvial fan environment, including fan deposits, mud flow deposits, and silt and sand of bajadas. The units are described in table 1, and their distribution is shown on plate 1. The mapping units are designated by letters, starting at the southeast end of the trench and proceeding generally northwestward and downward. Reference to points in plate 1 is given in meters for the *x* (horizontal) and *y* (vertical) coordinates, in that order, separated by a comma as in this example: (26.60, 3.05).

Stratigraphic units apparently do not correlate across the fault zone, except for units A and B which were continuous across the fault zone before they were displaced in 1915. Correlations of other units across the fault zone cannot be unequivocally ruled out, however, because alluvial fan deposition is so irregular that lithologic changes over short distances are the rule rather than the exception. If it is assumed that none of the units below B northwest of the fault are equivalent to units below B southeast of the fault, then it must be concluded, because of the down-on-the-northwest nature of fault displacement, that units L through P (a 2.5 m thick set of sediments) and possibly additional units, once overlay units C through K on the southeast side of the fault, but have been eroded off after the south-eastern block was raised relative to the northwestern block.

Soil horizons mapped in trench

Soils are described in Table 2. Two horizons, A and B, of the modern soil, m, (units mA and mB on plate 1) formed on the sediments of both the eastern and western blocks and are missing only where the 1915 rupture disturbed the ground surface. Buried paleosol, b1B, a B horizon, developed on stratigraphic unit H, is now restricted to the block southeast of the fault and lies at a depth of about 1.5-2 m. Two paleosol B horizons, b2B and $b2b_3$, developed on stratigraphic unit L, are now restricted to the block northwest of the fault and lie at a depth of between 1 and 2 m. Paleosol b3B, a B horizon, is preserved in stratigraphic unit M at a depth of about 2-3 m on the northwest side of the fault.

Only the modern soil units can be traced across the fault zone with certainty. Buried paleosols b1B and b3B have some similarities, but are interpreted to represent distinctly different periods of soil formation.

Age of units

The ages of sedimentary deposits cut by the trench are assumed to be of late Quaternary age because of their close association with modern alluvial fans. In more detail, the surface that forms the base of unit B may have formed after mid-Holocene (about 5,000 years before present) time, but more than a few thousand years ago. Because much of the evidence for these dates is ambiguous, a discussion of the data and lines of arguments are provided in the following section.

Discussion of dating evidence

Rodent bones were found at two locations in the wall of the trench. A single bone was found, apparently deposited as a sedimentary clast, within the sediments of unit L at (27.22, 2.95). A group of bones in a burrow 1.1 m below the ground surface in the buried paleosol, $B2B_3$, was found at 26.60, 3.05. The fossils were examined by C. A. Repenning, who found that two types of rodents are represented in the burrow: *Spermophilus townsendi* (Townsend ground squirrel) and *Peromyscus* sp. cf. *P. truei* (Pinon Mouse). Pertinent quotations from Repenning (1977, written communication) follow.

"The Pinon Mouse is somewhat north of its recorded range, but the difference does not seem significant; it is represented in the collection by a single first lower molar. The presence of the Pinon Mouse in a ground squirrel burrow is difficult to understand but Townsend Ground Squirrels have been observed to carry dead rodents to places of safety and to eat them there.

"The Townsend Ground Squirrel is a resident in the area; it is represented in the collection by a large number of bones representing at least three individuals, two of which were very large and very old. The squirrel builds two types of burrows: home burrows with nests and auxiliary burrows without nests that are near feeding places. The auxiliary burrows are used for protective shelters and may or may not be well drained. Home burrows have been reported as deep as 1.5 m but auxiliary burrows are smaller and shallower, averaging less than 0.5 m in depth. The age grouping of the collection, its position on the downthrown side of the fault and the fine-grained material in which it was found suggest an auxiliary burrow and there seems to have been no evidence of a nest (T. Kaplan-Henry, pers. communication). The suggestion thus would be that the burrow is auxiliary and related to a buried soil horizon rather than to the present land surface.

"Upon ignition, the bones clearly smell of 'burnt hair' indicating that considerable organic matter remains unleached within the bone. Experience has shown that this organic matter is leached out of bone under normal circumstances within about 10,000 years." (see for example, Quinn, 1957; Weston and others, 1973). The sample at (27.22, 2.95), containing the clast of bone from sediment unit L, "contains a fragment of a rodent radius that is indistinguishable from that of *Spermophilus townsendi* but is unidentifiable. It also smells of 'burnt hair' when ignited and is caliche-coated." No caliche was noted on the bones from the burrow.

A sample of the silty clay of unit K, the oldest unit exposed in the trench, was examined for diatoms and pollen by J. P. Bradbury but none were found.

Additional discussion of the uncertainties of interpretations of the above data is warranted, because of the importance of dating to the history of displacement along the fault. Two critical questions are: how certain is the age of the bone material, and what is the relation of the bones to the soil and stratigraphic unit?

Dating of the rodent bone material: Repenning (pers. communcation, 1980) reports that the strength of the burnt hair smell suggests a large proportion of unleached organic material, thus a date "younger than 5,000 ± years" might be more appropriate than 10,000 ± years. A modern age for the bone cannot be ruled out by this criterion, but the presence of a caliche coating on the bone fragment clast suggests an age older than modern.

Relation of rodent bones to paleosol b2B-b2B_3 and stratigraphic unit L: The apparent presence of one fragment of a rodent's radius as a sedimentary clast in unit L appears to be the strongest evidence that unit L, and thus also paleosol b2B-b2B_3, is as young as the rodent bone fragment. The reality of the single bone fragment being a sedimentary clast and not exotic, thus, is critical and supporting evidence would be helpful. The more abundant rodent bone material occurs in a burrow, but as outlined below, the argument of age relation of the burrow to the paleosol and stratigraphic unit is indirect.

The arguments that bone material in the burrow, and the burrow itself, relate to the top of unit L and paleosol b2B-b2B_3 rather than to the modern surface hinges primarily on the depth of the burrows. Hall (1946) reports that near Fallon, Nevada, Townsends Ground Squirrel had home burrows of adults at greatest depths of between 60 and 146.5 cm, and auxiliary burrows at greatest depths of between 30.6 and 45 cm. The depth of what may have been an auxiliary burrow at 1.1 m below the modern surface of the trench site thus seems to be excessive and suggests that it may not relate to the modern surface. If the burrow is a home burrow, the depth criteria would not rule out a relation to the modern surface. The absence of caliche on the burrow bones tends to favor a modern age for those bones.

If, indeed, the rodent burrow and bones relate to unit L and the paleosol rather than to the modern surface, the burrow may have been dug either near the beginning or near the end of the soil forming period, a period of time that could span thousands of years. Unit L must be older than the burrow, but how much older is indeterminate. It might be nearly contemporaneous, for example a few hundred years older, but it could be thousands of years older. Thus the bones in the burrow are of limited use in dating, and we must rely on the isolated bone fragment clast found at (27.22, 2.95) as evidence for the age of unit L.

The above arguments, at best, provide only a suggestion of a possible oldest age of about 5,000 years for the rodent bones, the paleosol and unit L. Evidence for the youngest ages possible are examined next.

After paleosol $b2B\text{-}b2B_3$ was formed, the following events took place: (a) uplift of the eastern block occurred causing at least paleosol $b2B\text{-}b2B_3$ to be eroded from the block east of the fault, forming a rather even surface as the base for mud flow unit B, (b) mud flow unit B was deposited, (c) loess A was deposited, (d) older scarp facets above that of 1915 declined from steep to angles as low as 9^o, and (e) soil horizons mA and mB were formed.

Deposition of mud flow unit B could have been accomplished in one flash flood, but deposition of loess unit A may have been a complex process, involving both periods of deposition and periods of deflation. Alternation of deposition and deflation of loess is still proceeding; but on the steeper slopes, which are remnants of pre-1915 scarps, and which are cut by the trench, erosion by wash probably currently exceeds deposition from dust storms. The nearness of the site to the floor of prehistoric Lake Lahontan and known deflation from the lake floor (Wallace, 1961) suggests that the loess was derived from there. The main period of deflation from the lake beds must have been after a large part of the lake had disappeared, a time considerably later than the last high stand of the lake about 12,000 ± years ago. However, the loess at the trench site may not be related to the period of major loess deposition at all. It may be relatively modern and some may even be transported by sheet wash from higher on the bajada slope. The age of the loess, thus, is probably less than 12,000 years but otherwise indeterminate.

The soil horizons mA and mB are not well developed, but must have required more than a few hundred years to form. For example, no soil has formed on loess bared by the 1915 displacement. Considering that only 15 to 20 cm of precipitation falls per year, one might estimate that as much as a few thousand years would be required for soil horizons mA and mB to form. Poor development of peds in the soil suggest an age no more than a few thousand years (R. Janda, personal communication, 1980, and E. Bell, personal communication, 1980.)

In summary, some of the data can be used to suggest that the surface that forms the base of unit B was formed after mid-Holocene (about 5,000 years B.P.) time, but more than a few thousand years ago. Much of the evidence is ambiguous or indeterminate.

Faults

Within the trench, a fault zone abruptly terminates several of the mapped units near x = 14. A zone approximately 1 to 1.5 m wide of fault rubble constitutes the fault zone. Southeast of the fault zone the sediments are predominantly of pebble or larger size gravel and have dips of between horizontal and 5°; northwest of the fault zone the sediments are predominantly of sand size or smaller and dip northwestward about 9^{0} near the fault. The fault rubble can be divided into southeastern and northwestern parts. The southeastern part consists of pebbles and cobbles in a matrix of silt, sand, and caliche. Many of the clasts have calcareous skins about 1-3 mm thick and are similar to those in units G and F. Fractures cut this rubble and many of them are highlighted by veinlets of calcareous material, particularly along the southeast side of the rubble zone. The northwestern part of the rubble is generally finer grained, consisting of a mixture of sand, silt, pebbles, and some cobbles. The northwestern part of the rubble is less consolidated than the southeastern part, and is subject to caving. The difference in consolidation suggests that the latest fault displacements were confined to the northwestern part of the fault zone, and this is further demonstrated by the lack of displacement of unit B and the modern soil where they overlie the southeastern part of the fault rubble (pl. 1).

Fractures outside the fault zone were examined for signs of displacement. A fracture zone as much as 0.1 m wide near $\underline{x}$ = 12 is highlighted by caliche which obscures the unit boundaries within the fracture zone. The units crossed by the fracture zone are not displaced. The fracture zone could not be traced to the surface or to the bottom of the trench. The lack of displacement and limited vertical extent suggests that this might have formed as a slump feature, the block to the northwest having tilted toward an open face of a fault scarp. Such features are common along the 1915 scarp. No other evidence of an open face is apparent, however, and the fracture may have formed as an extension crack at depth in response to tension across the whole zone.

A similar fracture is at about x = 17.5. This fracture seems to offset the contact between units L and N, but other units both above and below are not offset. The apparent offset may be just an irregularity in the contact.

Fault scarps

Almost the entire length of the trench was excavated on a degraded set of scarp facets resulting from repeated displacements of the fault. The spur above the scarps has a slope of 5^{o} to 6^{o} and the bajada below has a slope of 4^{o} to 5^{o}, but the degraded faults scarps have slopes of between 9^{o} and 23^{o}, and at least two facets are identifiable above the 1915 break. The top member of this set of old scarps can be seen at about x = 1.3 on plate 1. Between x = 1.3 and 10 is a fairly regular slope of about 9^{o} or 10^{o}, from x = 10 to x = 14 is a slope of about 14^{o}, and between x = 13 and x = 14.5 is a slope of approximately 23^{o}. The top of the zone at the surface that was disturbed by faulting in 1915 and consequent slope degradation is near 13.0 and extends west to about 15.3.

Amount and timing of displacements on faults

The amount and timing of prehistoric displacements on the fault was one of the principal goals of the project, but the evidence for ages of the units offset is ambiguous or indeterminate and only the modern soil and two sedimentary units can be correlated with certainty across the fault. Nevertheless, some useful conclusions can be reached. As discussed below, the 1915 displacement at the trench site was about 0.5 to 0.6 m, unit B was displaced about 0.3 m prior to 1915, and at least 0.2 m of displacement occurred between the formation of paleosol b2B-$b2B_3$ and the deposition of unit B. The evidence further suggests that the displacements in these events and all late Pleistocene through Holocene events on this part of the Pleasant Valley fault were small, probably 1 m or less.

Possible extrapolations of the bases of the modern soil horizons mA and mB and of the base of the mud flow unit B are shown in figure 3. The vertical component of fault displacement that occurred in 1915, based on the offsets of mA and mB, could lie between 0.49 and 0.86 m (table 3); however postulated 1915 displacements greater than about 0.65 m V. (vertical component) result in serious difficulties when the section is restored by displacements of that size (table 3). Such displacements require that prior to 1915 the top of unit B on the northwest (downhill) side of the fault extend above likely northwestward projections of the ground surface that lies southeast of the fault. Displacements of more than 0.64 m V. also require that prior to 1915 the base of mA was higher on the northwest (downhill) side of the fault than on the southeast side, which is a highly unlikely configuration. The evidence from the bases of mA and mB, the top of unit B, and projection of the ground surface that lies southeast of the fault thus indicate that the 1915 displacement had a vertical component between 0.49 m and 0.64 m. This is a maximum because the evidence does not exclude possible displacement after the formation of the bases of mA and mB but before 1915. As discussed below, the topography alone suggests a 1915 vertical component between 0.4 m and 0.6 m.

Reasonable extrapolations of the base of unit B indicate a vertical component of displacement between 0.78 m and 0.96 m (fig. 3 and table 3). The difference between these displacements and those indicated by bases of mA and mB suggests that a displacement of 0.14 m to 0.47 m occurred after the deposition of unit B but before 1915 and before the formation of the bases of mA and mB.

The discussion above regarding displacements assumed that no drag occurred during the 1915 faulting. Some of the sedimentary units and soils have a steeper dip just northwest of the fault ($\underline{x}$ = 14.5 to about 15.2) than they do farther northwest; moreover the more steeply-dipping parts are underlain by fault rubble, and any distributed faulting in the rubble would be conducive to flexing of the overlying units. To estimate the effects of such drag, the dip of unit B at the fault was adjusted to conform to the general dip that unit B has farther northwest, and the other horizons were adjusted accordingly. On figure 3, the adjusted position of base of mA is represented by point J, and the adjusted position of the bases of mB and unit B are represented by point K. The resulting estimates of displacement (table 4) are generally larger than the estimates listed in table 3. They also show a difference (0.13m to 0.42 m V.) between the displacements of the base of unit B and the bases of mA and mB, suggesting a pre-1915 displacement of unit B.

Whether or not drag occurred at the trench site in 1915 is not clear, but it probably did not. No obvious disruption of units was noted, but the postulated flexing is small (about 13^{0}) and could have been accomplished by distributed intergranular movements of small amount. The best evidence on the question is the size of the 1915 displacement inferred from the topography at the trench. Because of irregularities in the ground surface the 1915 displacement cannot be closely determined by this method but the indicated range is between 0.4 and 0.6 m. This amount is closer to the 0.5 to 0.6 m estimated from the trench data for displacement without drag (table 3) than the 0.7 to 0.8 m estimated for displacement with drag (table 4).

The evidence given above for a pre-1915 displacement of unit B is supported by the differences in thickness of unit B on the two sides of the fault. Unit B is generally thicker northwest of the fault than it is southeast of the fault, except near the ends of the trench (pl. 1). Two possible explanations for the difference in thickness are 1) unit B was deposited across a fault scarp and has always been thicker on the northwest; or 2) unit B, although initially of about the same thickness on both sides of the fault, has been uplifted and partly eroded southeast of the fault. If unit B was deposited across a fault scarp it probably would have been thicker just below the scarp but of "normal" thickness farther downslope; instead it has approximately the same thickness for about 12 m downslope from the fault. Deposition across a fault scarp is favored by the steeper dip of unit B just below the fault, but the steeper dip there could result from fault drag.

Under the second explanation, unit B was deposited with a more-or-less uniform thickness across the fault at a time when little or no topographic relief existed at the fault. Faulting then occurred and the uplifted part of unit B was partly eroded. One difficulty with this explanation is the manner in which the erosion could be accomplished. The site is near the end of a flat-topped spur that is less than 150 m wide and has only a small catchment area, but the spur does have a few shallow channels on top. Although the present topography does not seem conducive to much erosion, the environment did permit transport of the silty gravel of unit B, and could have permitted subsequent erosion of the unit under different conditions of rainfall.

That unit B southeast of the fault was originally thicker than it is today is shown by the effect of the relative displacements needed to match the base of unit B across the fault. All of the postulated displacements result in the top of unit B on the northwest side of the fault being higher than the present top of unit B southeast of the fault (tables 3 and 4).

Within about 8 m on each side of the fault, the average thickness of unit B to the southeast of the fault is 0.26 m less than it is to the northwest of the fault. If erosion was equal to the faulting, dip slip of 0.27 m and a vertical component of 0.26 m is implied for a fault dipping 75^{0}; this is within the range of pre-1915 displacements of unit B previously inferred.

Based on the discussion above the 1915 displacement at the trench site was most probably in the range of 0.5 to 0.6 m V, and unit B probably has been displaced about 0.8 to 0.95 m, of which 0.2 to 0.35 m occurred prior to 1915.

The paleosol horizon b2B on unit L is well developed and extends almost continuously from the northwestern end of the trench to the fault. This soil probably extended southeastward across the fault originally, but its southeastern portion has been faulted upward and removed by erosion in the vicinity of the trench.

The possible minimum vertical component of displacement of the base of paleosol horizon b2B is diagrammed in figure 4. The paleosol horizon is not recognized east of the fault zone; thus east of the fault zone the base of the horizon must have been above the base of unit B, and a minimum value of 1.15 m displacement is interpreted.

One or more displacement events thus produced a vertical component of displacement of at least 0.2m (minimum offset of b2B, about 1.15 m, less the maximum offset of the base of unit B, about 0.95 m) in the interval of time between the cessation of soil forming processes responsible for b2B and the planation of G, F and L to form the base for unit B.

Other variations in correlation and interpretation can be imagined, but quantification of other displacements older than the displacement of the base of unit B remains ambiguous. If the exposed sedimentary units southeast and northwest of the fault are not equivalent units, at least 6 or 7 m of total displacement across the fault is represented by the record in the trench.

Significantly, no unit northwest of the fault is in the form of a wedge; that is, thick against the fault and thinning northwestward, nor do the units contain a concentration of large clasts near the fault and finer clasts away from the fault. Such types of sedimentary structures and lithologic variation should be present, if scarps of a meter or more high stood at the fault line. To make the point another way, nothing in the record of sedimentation suggests that a large fault scarp stood in relief uphill of the sedimentary units L, M, N, O and P. Two interpretations are suggested: First, no scarps stood while L, M, N, O and P were being deposited. Perhaps no fault displacement extended into the pile of sediments before paleosol horizon $b2B_3$ formed, thus that no 6 or 7 meters of displacement occurred and that the units C through K are correlatives of units L through P. This argument is contradicted by the width of the fault zone (1.5 m), and the generally coarser nature of the units southeast of the fault zone compared to units northwest of the fault zone, which argue for cumulative displacements measured in many meters. Second, and more likely, individual displacements were so small and relief so low along the scarps formed, that the perturbation of sedimentation downhill of the scarps is obscured in the general heterogenity of fan deposition.

The degraded fault scarps across which the trench was cut provide some additional evidence both of number of past fault displacements and their ages (Wallace, 1977, and Bucknam and Anderson, 1979). The degraded fault scarps appear as facets of different slopes. The facet having a slope of 23^{o} is interpreted as the local expression of the 1915 fault scarp, which in other places nearby has a free face. It has a height of about 0.6 m. The next higher facet slopes 14^{o} and also has a height of 0.6 m, suggesting an age in the last half of the Holocene. The highest facet, which slopes 9^{o}-10^{o}, has a height of 1.5 m. This slope-height ratio suggests an early Holocene or late Pleistocene age (Bucknam and Anderson, 1979), but the scarp may be composed of more than one facet. This scarp facet evidence may be interpreted as suggesting at least two displacement events in the Holocene or late Pleistocene prior to 1915, but exactly what the timing might have been appears indeterminate from the data available. Just how the processes of slope decline of the scarp facets, the deposition and partial erosion of mud flow unit B, the deposition of unit A, and the development of the modern soil are interrelated cannot be resolved with present data, but if it could be, a significant record of fault displacement might be interpretable.

Summary

An exploratory trench was excavated across the 1915 trace of the Pleasant Valley fault near the north end of the Pearce scarp segment. The trench revealed sixteen mappable sedimentary units and four soils, including three buried paleosols. The mapped units are of late Quaternary age and some rodent bones possibly 5,000 years old were found in the one of the higher stratigraphic units.

Faulting is very clearly represented in the trench by the abrupt termination of several of the units where they abut against a zone of fault rubble as much as 1.5 m wide. The fault rubble constitutes the fault zone as exposed in the trench; although fractures were noted outside the fault rubble, dip-slip fault displacements have not occurred on them. To the southeast of the fault zone the sediments are predominantly of gravel size or larger and have very low dips whereas to the northwest they are predominantly of sand size or finer and dip northwestward about 9°. Only the uppermost units could be correlated across the fault.

Displacement of about 0.5 to 0.6 m (maximum vertical component) that occurred in 1915 is recorded by two sedimentary units and the modern soil, and an earlier displacement of about 0.3 m at a time possibly less than 5,000 years ago is also represented. Additionally, a paleosol is displaced at least 1.15 m also at a time possibly less than 5,000 years ago, but before a few thousand years ago.

Most of the trench was located on a degraded set of fault scarps composed of four facets having slopes of $9\text{-}10^{\circ}$; 14°; 23°; and an irregular surface. The lower two facets are believed to have been produced in 1915, with modifications later. Topographic evidence suggests that about 0.4-0.6 m of this scarp height is the result of the 1915 displacement, and the heights of the higher facets are 0.6, and 1.5 m in order above the 1915 scarps. The number and ages of earlier events associated with the facets are uncertain, but the slope-height ratios suggest a Holocene to late Pleistocene age for them.

Displacement events prior to 1915 cannot be accurately dated because of the many pieces of indeterminate evidence, but that several did occur in late Pleistocene and Holocene time is certain. Of significance is the conclusion that all of these displacements at this site were small, probably less than 1 m.

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References cited

Bucknam, R. C. and Anderson, R. E., 1979, Estimation of fault-scarp ages from a scarp-height-slope-angle relationship: Geology, v. 7, p. 11-14.

Hall, E. R., 1946, Mammals of Nevada: Contributions from the Museum of Vertebrate Zoology, University of California, Berkeley; University of California Press, Berkeley and Los Angeles, p. 297-298.

Quinn, J. H., 1957 (untitled news note): Society of Vertebrate Paleontology News Bulletin, n. 51, October, p. 18.

Wallace, R. E., 1961, Deflation in Buena Vista Valley, Pershing County, Nevada: in Geological Survey Research 1961: U.S. Geological survey Professional Paper 424-D, p. D242-D244.

_____1977, Profiles and ages of young fault scarps, north-central Nevada: Geological Society of America Bulletin, v. 88, n. 9, p. 1267-1281.

_____1980, Map of scarps formed during earthquake of October 2, 1915, Pleasant Valley, Nevada, and other young fault scarps: U.S. Geological Survey, Open-file Report no. 80-608.

Weston, R. J., Repenning, C. A., and Fleming, C. A., 1973, Modern age of supposed Pliocene seal, Arctocephalus caninus Berry (-Phocarctas Lookeri Gray), from New Zealand: New Zealand Journal of Science, v. 16, p. 591-598.

Table 1. Sedimentary units mapped in the trench

Unit	Description
A	Grayish orange unconsolidated laminated silt; laminations 0.5-1 mm thick. Contains scattered pebbles of low sphericity that are flat-lying. Largely a loess deposit, but from x = 12.7 to x = 14.6 (at the fault zone) consists of loose silty debris containing pebbles and some cobbles; this part may have formed as slope deposits during degradation of the 1915 scarp.
B	Very pale orange friable silty gravel. Clasts range from 4-64 mm, are coated with calcium carbonate, and are separated by a calcareous silty to sandy matrix containing voids <1 mm in diameter. This is probably a mudflow deposit. It has a modern soil profile developed on it.
C	Yellowish brown compact silty gravel. Most clasts are in 8 mm-32 mm class, but are subangular, have medium sphericity with long axis horizontal. Matrix, of silt to sand sizes, is slightly calcareous, has a "crumb" appearance. Some clasts are partially covered with a calcareous "skin." Unit may be a mudflow deposit that has undergone some pedogenesis.
D	Grayish orange pebble gravel. Clasts range from fine pebbles to cobbles, are poorly sorted; most are flat-lying but locally imbricated with long axes inclined downward to E.; partially coated with clacareous "skin" 0.25 mm thick. Has irregular contacts; probably a channel deposit.
E	Grayish orange silt and very fine sand, well sorted. Unit is compact but has voids 1 mm or less in diameter, has discontinuous laminations 1 mm to 3 mm thick. Uneven fracture produces peds about 5 mm in diameter. Iron oxide marks most of basal contact. Contains scattered 8 mm to 16 mm pebbles. May be primarily loess that has undergone some pedogenesis.
F	Moderate reddish brown to moderate orange pink pebble gravel. Moderately well sorted, not much matrix; most clasts are of fine to very coarse pebble size but range form coarse sand to cobbles. Clasts have low sphericity; most are randomly oriented but some are flat-lying. Probably a channel deposit.
G	Very pale orange somewhat indurated pebble gravel. Unit is poorly sorted; although most clasts are of coarse pebble size, they range from granules to cobbles. Most clasts have high sphericity and no preferred orientation was detected.
H	Moderate yellowish brown friable silty pebble gravel. Clasts mostly of medium pebble size, have low to moderate sphericity, are randomly

Table 1. (continued)

Unit	Description
	oriented, are "floating" in the matrix and do not touch one another. Matrix chiefly of silt but ranges from clay to fine sand size. Unit contains a lens and beds of well sorted pebble gravel (unit I). Buried soil preserved over part of its extent.
I	Loose pebble gravel. Iron oxide staining gives it a dark yellowish orange color. Pebbles mostly 4 mm-16 mm in diameter, well sorted.
J	Pale yellowish orange cobble gravel. Moderately well sorted, most clasts consisting of very coarse pebbles and cobbles. Clasts touch one another; sand and silt fills most spaces between large clasts. Many clasts are flat lying and others are imbricated, inclined downward to southeast.
K	Pale olive pebbly silty clay. Scattered clasts, mostly of pebble size but including a few cobbles, are randomly oriented. Matrix breaks into uneven peds 5 mm to 10 mm in diameter with smooth shiny faces. No voids were seen in matrix. Unit probably is a mudflow deposit.
L	Grayish orange loosely packed pebbly silt and sand. Poorly sorted; grain sizes range from silt to granules and scattered pebbles. Coarse clasts are randomly oriented, coated with calcareous "skins" 1 mm to 3 mm thick. Matrix calcareous, has soil developed on part of it.
M	Grayish orange pebbly silty clay. Contains scattered medium to coarse pebbles, randomly oriented, partially coated (usually on bottom) by calcareous "skin." Matrix has small (1 mm) voids throughout, is highly calcareous. Buried soil preserved on top of this unit.
N	Pebbly silty clay. Very similar to unit M but lacks well-developed soil.
O	Very pale orange friable silty pebble gravel. Pebbles are in contact with one another, are mostly in coarse to very coarse size range, are randomly oriented, have partial calcareous coatings, mostly on lower parts of pebbles. Matrix ranges from silt to sand size, is highly calcareous.
P	Moderate yellowish brown silty pebble gravel. Most larger clasts are 4 mm to 16 mm in diameter but a few are of cobble size; they are in contact with one another, and have thin calcareous coatings. Matrix ranges from silt to very fine sand, is slightly calcareous, contains clumps of iron oxide cement. Unit has a crumbly fracture; pebble sizes seem to decrease upward, and has gradational contact with overlying unit.

Table 2. Soils

Soil	Color	Texture	Structure	Other
Modern				
mA	Very pale orange 10 YR 8/2* (dry) to moderate yellowish brown 10 YR 5/4 (wet).	Silty	Uneven, earthy fracture	Not calcarerous. Many voids 0.1 mm to 0.5
mB	Moderate yellowish brown 10 YR 5/4 (dry) to dark yellowish brown 10 YR 4/2 (wet).	Clayey silt	Peds not well developed, fracture uneven and crumbly, polygonal, 10±-20 mm.	Not calcareous. Clay skins poorly developed. Many voids 0.1 mm to 0.5 mm.
Buried b1B	Moderate yellowish brown 10 YR 5/4 (dry) to moderate brown 5 YR 4/4 (wet).	Mostly silt	Peds poorly developed, 3 mm, to 15 mm, crumbly fracture.	Mottled with veinlets of carbonate. Clay skins poorly developed.
Buried b2B	Pale yellowish brown 10 YR 6/2 (dry) to dark yellowish brown 10 YR 4/2 (moist).	Clayey silt	Peds well developed, especially west of x = 26, break out easily, are 10 to 20 mm dia.	Mottled with carbonates. Has voids <0.5 mm dia.
$b2B_3$	Pale yellowish brown 10 YR 6/2 (dry) to dark yellowish brown 10 YR 4/2 (moist).	Clayey silt	Peds poorly developed, about 5 mm to 10 mm, crumbly fracture.	Mottled with carbonates Clay skins poorly developed.
Buried b3B	Moderate yellowish brown 10 YR 5/4 (northwest of x = 18.7) to moderate brown 5 YR 4/4 (southeast of x = 18.7).	Clayey silt	Peds poorly developed, have crumbly polygonal fracture, about 2-10 mm.	Extensively mottled with carbonates. Carbonate veinlets seem to have formed in ped fractures west of x = 18.7.

*Munsell color designation

Table 3. Estimates of displacements without allowance for drag

Reference	Match Points	Displacement, m Dip Slip	Vertical Component	Effect of relative movement of the two sides of the fault by the given displacements
Base of mA	A-E	0.66	0.64	Acceptable join of base of mA and mB, but gives part of base of mA a flat slope. Top of unit B northwest of fault extends above projections of ground surface that is SE of 1915 fault scarp, unless projections include an unlikely near-horizontal segment.
	B-E	0.51	0.49	Good join of base of mA, acceptable join of base mB; requires thin mB near fault, but acceptable. Top of unit B is near or above ground surface as projected from southeast.
Base of mB	C-F C-G	0.67 0.70	0.65 0.68	Effects similar to A-E above. Base of mA on NW (downhill) side of fault slightly higher (0.04m) than base of mA projected horizontally from SE side. Top of unit B northwest of fault extends above projection of 14° slope that is southeast of 1915 fault scarp.
	C-H	0.89	0.86	Base of mA on NW side of fault is substantially higher (0.23m) than base of mA projected horizontally from SE side. Top of unit B extends far above projections of ground surface that is SE of 1915 fault scarp.
	D-F	0.60	0.58	Acceptable join of base of mA; other effects intermediate between A-E and B-E.
	D-G	0.63	0.61	Acceptable join of base mA; other effects similar to A-E.
	D-H	0.82	0.79	Base of mA on NW side of fault is substantially higher (0.16m) than base of mA projected horizontally from SE side. Top of unit B extends above horizontal projection of ground surface just SE of 1915 fault scarp.

Table 3 (continued)

Base of unit B	A-F	0.96	0.93	Top of unit B on NW side of fault would have been higher than a horizontal projection of unit B from SE side of fault if unit B had its present thickness SE of fault.
	A-G	0.99	0.96	Same
	B-F	0.81	0.78	Same
	B-G	0.84	0.81	Same

Table 4. Estimates of displacement allowing for postulated drag.

Reference	Match Points	Displacement, m Dip Slip	Vertical Component	Effect of relative movement of the two sides of the fault by the given displacements.
Base of mA	A-J	0.86	0.83	Requires unlikely flat slope for top of unit B at the fault. Base of mB requires short flat slope.
	B-J	0.71	0.69	Top unit B is above projection of 14^{0} slope SE of 1915 scarp but below horizontal projection. Base mB about .07m too low on NW, but acceptable
Base of mB	C-K	0.86	0.83	Same as A-J
	D-K	0.79	0.76	Top of unit B above projection of 14^{0} slope SE of 1915 scarp but below horizontal projection: base mA makes good fit.
Base of unit B	A-K	1.15	1.11	Top of unit B on NW side of fault would have been higher than a horizontal projection of unit B from SE side of fault if unit B had its present thickness SE of fault.
	B-K	0.99	0.96	Same

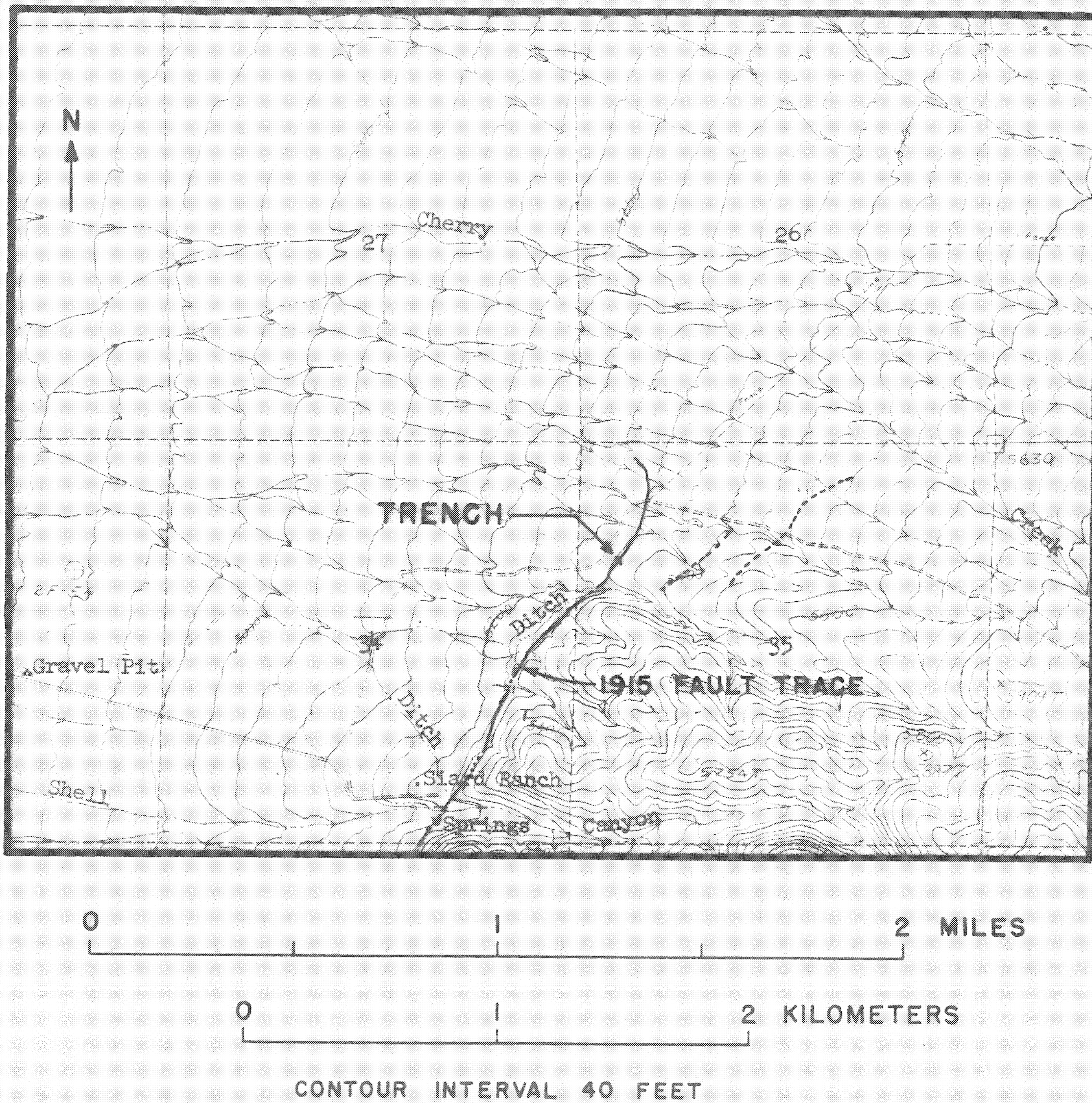
N
Cherry
27
26
TRENCH
Creek
5630
Ditch
34
35
Gravel Pit
1915 FAULT TRACE
Ditch
Siard Ranch
Shell
Springs
Canyon
0
1
2 MILES
0
1
2 KILOMETERS
CONTOUR INTERVAL 40 FEET

Fig. 1

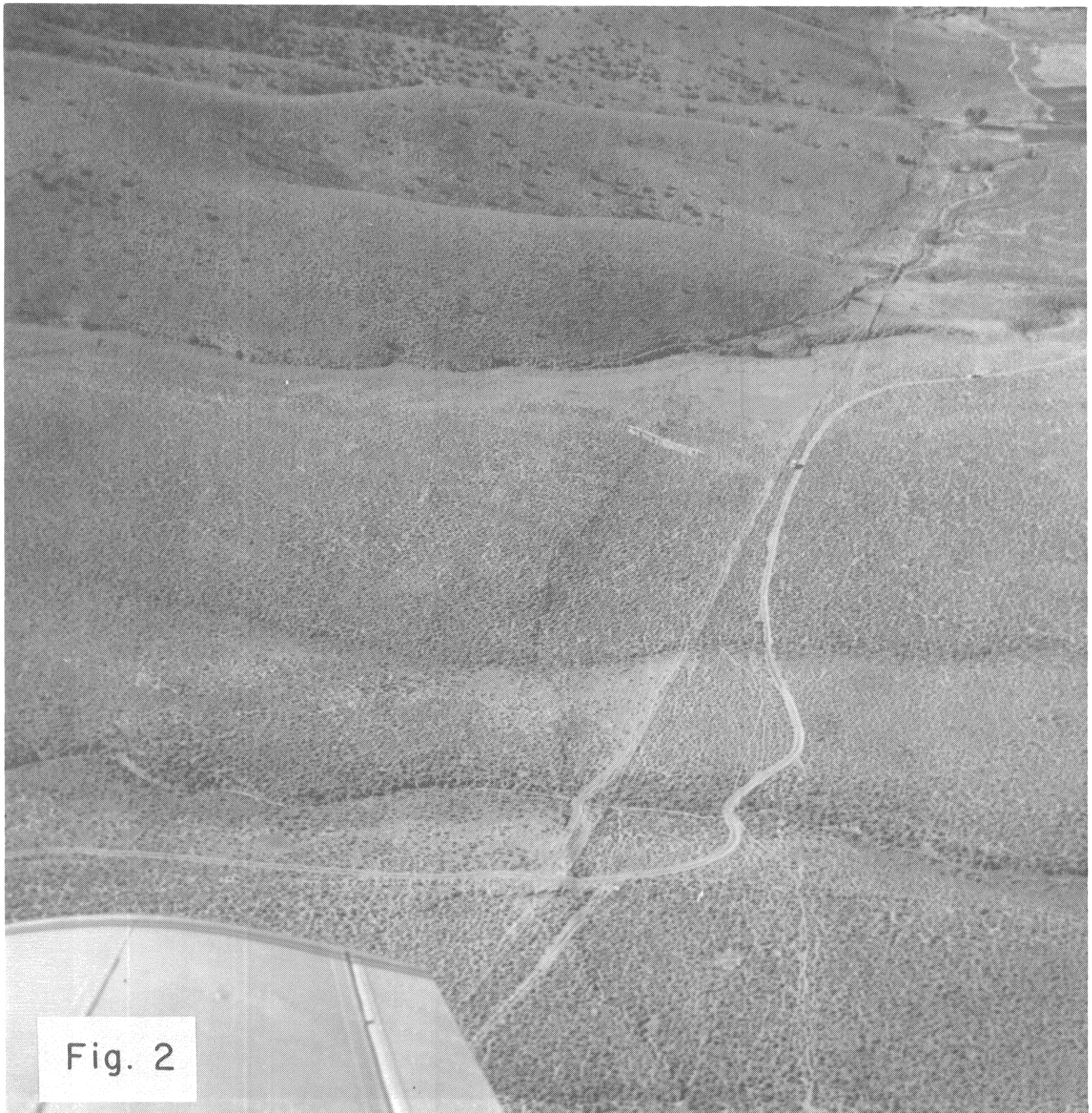

Fig. 2

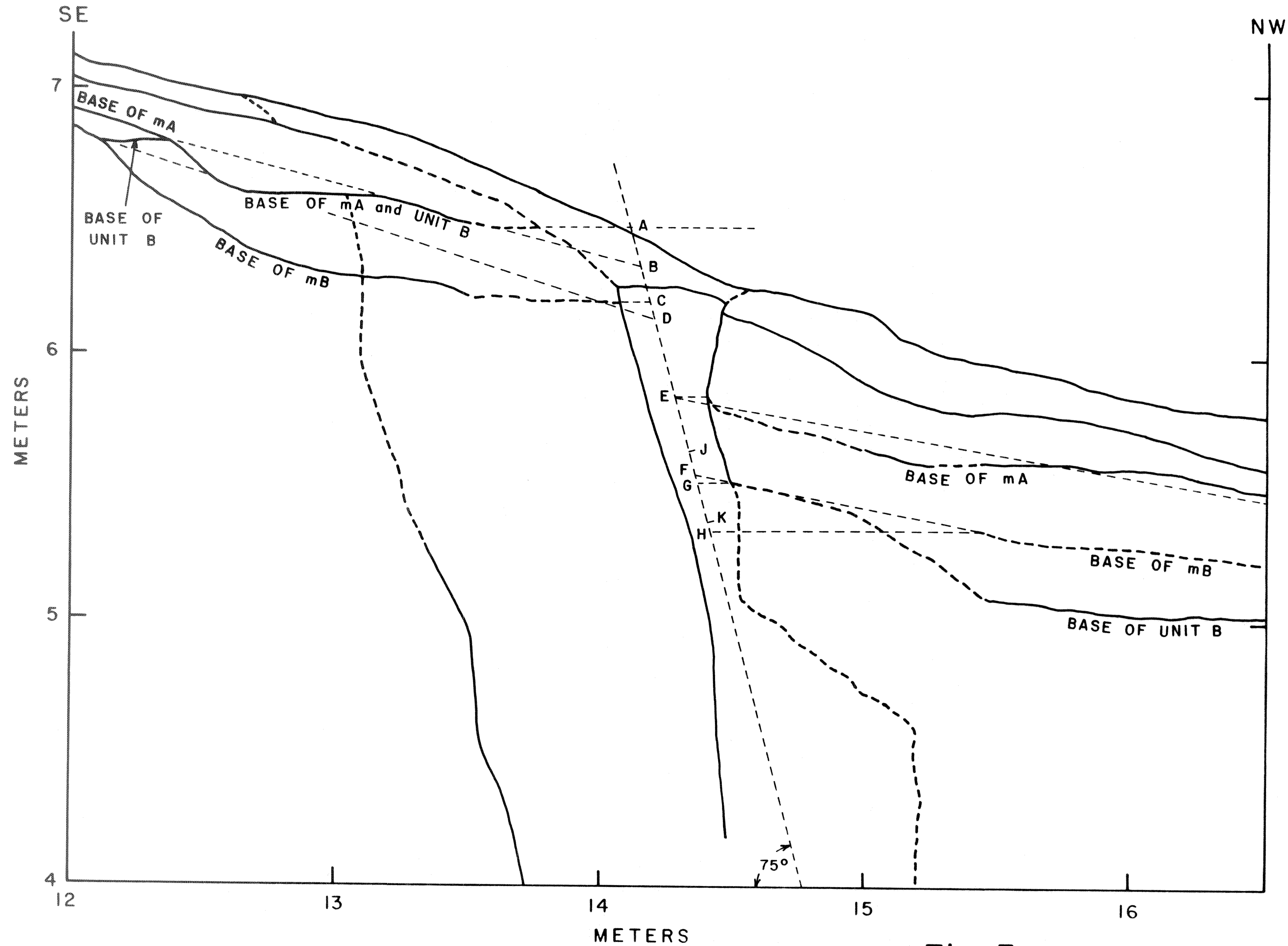
SE
NW
7
6
5
4
12
13
14
15
16
METERS
METERS
BASE OF mA
BASE OF UNIT B
BASE OF mA and UNIT B
BASE OF mB
A
B
C
D
E
J
F
G
K
H
BASE OF mA
BASE OF mB
BASE OF UNIT B
75°

Fig. 3

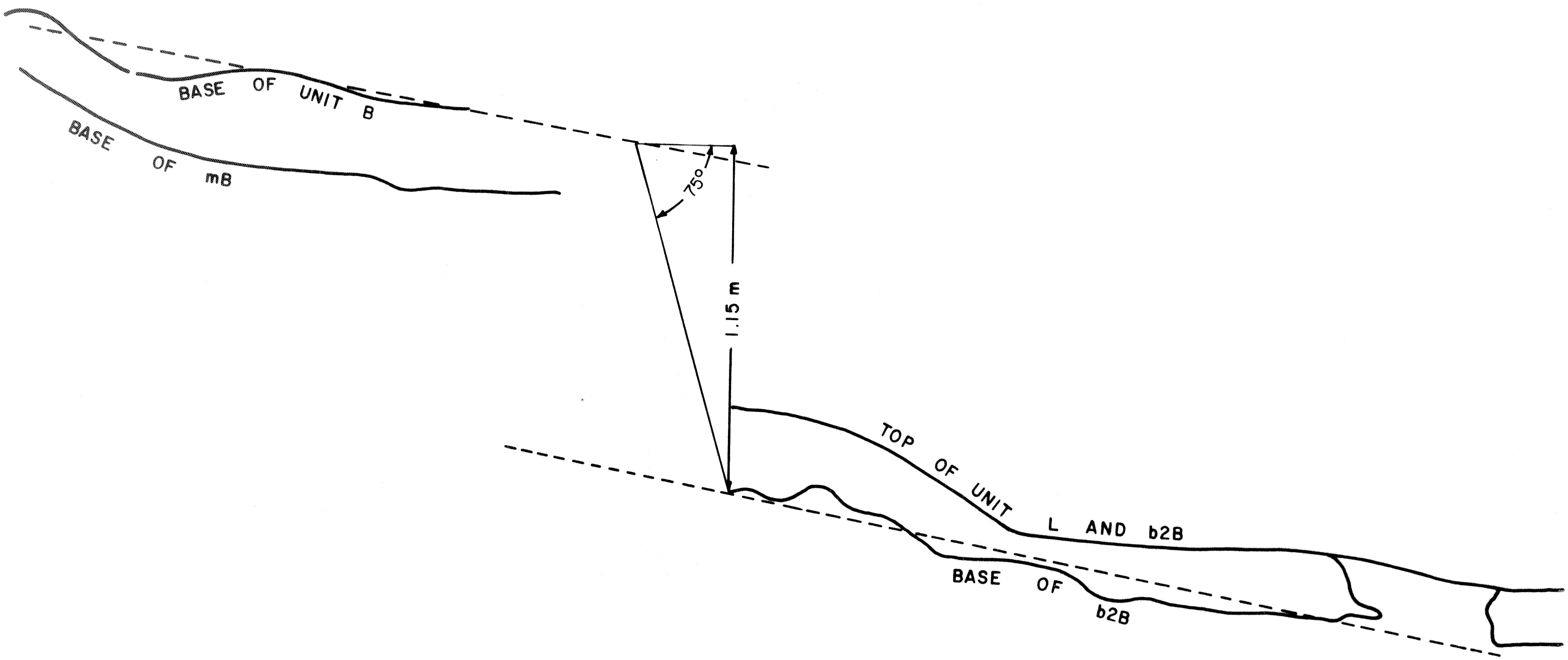
BASE OF UNIT B
BASE OF mB
75°
1.15 m
TOP OF UNIT L AND b2B
BASE OF b2B

Fig. 4