CALIFORNIA DIVISION OF MINES AND GEOLOGY
SUPPLEMENT NO. 2 TO FER-127
CORDELIA FAULT
SOLANO COUNTY, CALIFORNIA

by
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INTRODUCTION

Traces of the Cordelia fault were originally zoned for special studies in the Cordelia 7.5-minute quadrangle in 1983 (CDMG, 1983; Bryant 1981). Four investigations for the hazard of surface fault rupture have been conducted across traces of the Cordelia fault since the Official SSZ Map of the Cordelia fault was issued in 1983 (Carie and Wigginton, 1989 [DMG file no. C-773]; Vahdani and others, 1990 [DMG file no. C-768]; Cole and Pratt, 1991 [DMG file no. AP-2521]; Levish, 1991 [DMG file no. C-784]). Significantly, Vahdani and others reported evidence of Holocene faulting along the Cordelia fault that previously was not zoned (Figure 1). This new information requires a re-evaluation of traces of the Cordelia fault north of Highway 80.

SUMMARY OF NEW DATA

Evidence of Holocene activity along the Cordelia fault was reported at two site investigations in the vicinity of Highway 80 (Cole and Pratt, 1991; and Vahdani and others, 1990).

REPORT AP-2521

A site investigation for a proposed freeway interchange by Cole and Pratt (1991), performed just south of Interstate Highway I-80, reported evidence of Holocene activity along a previously zoned trace of the Cordelia fault (Cole and Pratt's trench T-4) (Figure 1). The western half of the trench has a distinctive $CaCO_3$ horizon within their unit 3 alluvial deposit that doesn't appear as well-defined across the inferred fault in the eastern end of the trench, suggesting offset of this alluvial/esturine deposit. Bates (1977) mapped the Clear Lake clay soil where trench T-4 is located. The Clear Lake clay is a young Holocene soil characterized by an A-C horizon. Weak stage I pedogenic carbonate was reported by Cole and Pratt and is thought to indicate a mid-Holocene age for the offset alluvium.

No fault planes or slickensides delineate the fault in T-4. A possible horst in unit 4 alluvium (gleyed sandy clay) is located between stations 30 and 35. The $CaCO_3$ horizon in unit 3 has an apparent vertical separation (down to the east), although this is subtle. Cole and Pratt postulated that a difference in groundwater elevation exists across the fault and probably explains the vertical separation of the $CaCO_3$ horizon in unit 3.

REPORT C-768

A site investigation by Vahdani and others (1991), located just north of Highway 80, reported evidence of Holocene displacement along a trace of the Cordelia fault not previously zoned (Figure 1). Six trenches totaling 290 meters and as much as 3 meters deep were excavated across traces of the fault. Evidence of Holocene displacement was reported in trenches A, B, C, and E. Shears extend into unit 2A, which is described as a yellow brown to orange brown slit to sandy silt. Vahdani and others concluded that unit 2A is Holocene, based on the density, degree of induration, consolidation, presence of $CaCO_3$, pedological structures, and weathering profile. Bates (1977) mapped a contact between two soil units coincident with the fault trace exposed in the trenches. The fault apparently juxtaposes the Antioch-San Ysidro complex on the west against the Clear Lake clay on the east. The Clear Lake clay is a young Holocene soil characterized by a weakly developed A-C horizon. The Antioch series is characterized by a moderately well-developed soil horizon with 4 Bt horizons totalling 45 to 104 centimeters thick, moderately thick clay films, coarse prismatic to weak angular blocky structures, indicating a late Pleistocene to early Holocene age for the geomorphic surface.

The fault zone in trench A is up to 5.5 meters wide and consists of three principal splays. Individual shear zones are up to 30 cm wide and are characterized by partially open fractures (to 0.5 cm wide). Water issues from the fractures at a rate of about 1 gallon per minute. Shears in a late Pleistocene alluvial unit (unit 3) are delineated by loose breccia. Significant right-lateral displacement is indicated by the discontinuity of sub-units within unit 2B across the fault. Also, unit 2B thickens on the east side of the fault at station 97 in trench C.

The fault was not found in trenches D and F. Vahdani and others suggested that the fault changes to a more easterly trend north of trench E, indicating a right step or bend in the fault.

REPORT C-310

About 76 meters north of Vahdani and others' trench F is the 1978 Dever and Anderson (C-310) site investigation, initially evaluated in FER-127 (Bryant, 1981) (Figure 1). Three trenches totaling about 73 meters were excavated across the trace of the Cordelia fault mapped by Helley and Herd (1977). Trench 1 encountered alluvial deposits consisting of gleyed to oxidized clayey silts and sands with some grey gravel, all overlying weathered Sonoma Volcanics. An open crack was reported at about station 175 at the eastern end of the trench. The crack was located in blue-grey, wet, sandy clay with residual pumiceous pebbles and angular crystal fragments, suggesting weathered Sonoma Volcanics. However, an alternative explanation could be that this unit is a Pleistocene alluvial unit. The crack extended above this unit into a thin, lenticular gravel lens and is apparently truncated by a younger fine to medium sand lens overlying the grey gravel unit. There was no apparent vertical separation between contacts of units. The crack was issuing "significant" quantities of water (no quantitative estimate). Dever and Anderson reported that the crack was not delineated by fault gouge or slickensides and concluded that the crack was not fault related.

Two short trenches (12 meters and 15 meters) were excavated to the south and no evidence of the crack was reported. Dever and Anderson concluded that no evidence of faulting was observed and that there was no surface fault rupture hazard. Additionally, a geophysical survey (seismic refraction) did not locate abrupt changes in seismic velocities across a linear zone, changes in depths to seismic discontinuities (depth to water table), and changes in transmission characteristics of seismic energy.

Although trenches T-2 and T-3 did not encounter the crack, it is entirely possible that these short trenches did not cross the southern projection of the crack. That the seismic refraction survey did not find evidence of a seismic velocity difference may not preclude the presence of a fault in what may be relatively homogeneous units of the Sonoma Volcanics. In retrospect, the fact that no fault gouge or slickensides were reported may not be significant because the flow of groundwater issuing from the crack may have washed out brecciated material. It is perhaps significant that a thin lens of gravelly sand is located over the fracture because similar deposits were observed overlying, and are disrupted by faults in the investigation by Vahdani and others (1990).

ADDITIONAL CONSULTING REPORTS

REPORT C-773

Two trenches totalling 79 meters were excavated across the Cordelia fault by Carey and Wigginton (1989) (Figure 1). The consultant stated that only minor faults in Pliocene Sonoma Volcanics were observed and concluded that these minor bedrock faults resulted from local folding of the Sonoma Volcanics. Overlying alluvium/colluvium is very thin and presumably quite young (mid to late Holocene).

A possible fault in trench T-1 (station 89) is delineated by a minor soil-filled fissure. The overlying soil (light brown clayey silt) thickens over this fissure, a possible suggestion of fault recency. Two very minor faults reported at station 85 correspond to a prominent swale identified on aerial photographs by the consultants and this writer (Figure 1). The overlying soil (colluvium) thickens over these two minor faults, but evidence of faulting in the overlying colluvium was not reported.

It is clear that the minor faults reported in the trenches excavated by Carey and Wigginton are not as impressive as the exposure of the Cordelia fault at Rockville Road (locality 1, Figure 1; see description in Bryant, 1981). It is reasonable to assume that the faults exposed in the trenches are on strike with the fault exposed at locality 1. However, trench T-1 may not have extended far enough to the west to expose possible faulting along an east-facing scarp at locality 2 (Figure 1). Here a resistant andesite unit on the west is juxtaposed with ashflow tuff on the east along a generally linear contact. D. Carey (p.c., June 1991) suggested that the andesite overlies tuff and that the escarpment is erosional. However, the linearity of the ridge or escarpment suggests faulting rather than erosion.

REPORT C-784

Five trenches were excavated across the trace of the Cordelia fault north of locality 1 by Levish (1991) (Figure 1). These trenches were inspected by G. Borchardt and this writer September 23 and 24, 1991. R. Martin and J. McMillan of DMG were also present on September 23.

T-1 totalled 26 meters long and was 1.5 meters deep, although only the eastern 13.7 meters were logged due to extremely resistant ash-flow tuff (Figures 1, 2). The eastern end of the trench intercepted the fault exposed at locality 1 (T-1 located about 15 meters north of the road). The width of the fault zone is about 9 meters. Individual shears generally trend from N02°E to N05°W and dips range from near vertical to 82° E to 62°E. At my station 20 a soil-filled fissure extends to the bottom of the trench. The fissure-fill deposit contains "micro Bt horizons" indicative of a drying pulse. Borchardt (p.c., 9-91) interprets the age of these micro B horizons to be younger than 9 ka, indicating a Holocene age for the fissure-fill deposit. This soil-filled fissure (located and logged on the south wall of the trench) did not extend to the north wall of the trench. There was, however, a fault on strike that truncates bedrock units. There is no offset of the overlying A soil horizon (as reported by Helley and Herd, 1977), though this is a soil that probably has developed less than 5 ka.

Trench T-2 is a short (less than 15 meters), 1.5 meter deep pit excavated about 60 meters north of T-1 (Figure 1). A well-defined fault zone was not observed in fractured ashflow tuff, but a similar soil-filled fissure was observed near the west end of the trench and is on trend with the Cordelia fault.

T-3a was excavated near the western side of a linear trough in bedrock thought to delineate the Cordelia fault (Helley and Herd, 1977; Bryant, 1981) (Figure 1). The trench was about 15 meters long and at least 2.4 meters deep at the western end. The exposure revealed fractured volcanic bedrock on the west side juxtaposed in fault contact (N05°E, near vertical) with latest Pleistocene to Holocene alluvial/colluvial deposits - poorly sorted colluvium and poorly sorted fluvial gravels. A well-developed paleosol (Bt horizon) was observed at the eastern end of the trench about 1.2 meters below the ground surface. This horizon was characterized by 7.5YR to 5YR colors, thick illuvial clay films, and a very indurated character, suggesting a significant age, possibly 200 ka (Borchardt, p.c, 9-91). This unit did not extend to the west end of the trench, dying out before or truncated against younger, overlying colluvial/alluvial deposits. A poorly developed stoneline was observed about 0.75 meters below the ground surface. This stoneline did not extend across the fault, suggesting that either the stoneline formerly existed across the fault and subsequently had been eroded, or had been truncated by faulting.

T-3b was a test pit excavated about 10 meters north of T-3a (Figures 1,3). The test pit was 4.5 meters long and about 1.5 meters deep. Relationships similar, but less clear, were observed in T-3a and T-3b. The bedrock unit on the west was juxtaposed with pre-Holocene colluvial/alluvial deposits on the east. There was no well-defined fault plane separating these units. One and possibly two stonelines were observed. The lower stoneline apparently truncates against bedrock to the west. The upper stoneline does not continue west across the fault, but it is not clear if the stoneline is truncated by the fault or if the stoneline originated from the west from a now-eroded small escarpment. The colluvial unit underlying the upper stoneline contained thin, patchy clay films, suggesting a pre-Holocene to early Holocene age of the unit.

T-4 was excavated at the northern end of the linear trough (Figure 1). The trench consisted of two parallel pits each about 6 meters long, overlapped and about 1.5 meters deep. No clear evidence of faulting was observed. The western end of the trench contained jointed and fractured andesite and the eastern end consisted of Holocene colluvium consisting of subrounded cobbles and boulders of andesite with a dark brown silty sand matrix. No shears or fault planes were observed in the trenches. A soft, near vertical krotovina seemed to separate the colluvium and bedrock on the northern wall of the trench, but the southern wall contained neither the krotovina nor a fault plane. Ashflow tuff, located in exposures east of the trench, was not observed in the trench excavation.

AERIAL PHOTOGRAPHIC INTERPRETATION AND FIELD INSPECTION

Aerial photographic interpretation by this writer of traces of the Cordelia fault north of Highway 80 was accomplished using photographs from Cartwright Aerial Survey (1973), U.S. Department of Agriculture (USDA 1952), and U.S. Geological Survey (1974). Selected features were field checked by this writer, G. Borchardt, and E. Hart in June, July, and September 1991, totalling about 3.5 days of field time.

The Cordelia fault zone north of Highway 80 is characterized by a broad zone of discontinuous traces delineated by linear drainages, linear ridges and breaks in slope, some fault line scarps, linear troughs, and, locally, right-laterally deflected drainages (Figure 1). Geomorphic evidence of systematic right-lateral strike-slip displacement generally is moderately to poorly defined.

The western trace of the Cordelia fault is characterized by an east-facing bedrock scarp, a linear trough and drainage, and a broad west-facing escarpment or break-in-slope (Figure 1). Trench exposures by Carey and Wigginton (1989) and a nearly continuous bedrock exposure along a canal excavation (locality 3, Figure 1) suggest that this western trace may not continue to the south as mapped by Helley and Herd (1977) (see Bryant, 1981). However, it is possible that the trench investigation by Carey and Wigginton did not expose the main trace delineated by the east-facing escarpment that juxtaposes andesite against tuff. Similar lithologic relationships exist at the Levish site which did expose a fault contact between andesite and tuff. The principal trace may jog or bend to the east (Figure 1). This easterly trace is delineated by vague tonal lineaments (locality 4) and geomorphic features in bedrock such as benches, linear ridges and valleys, and a possible right-laterally deflected drainage (Figure 1).

An exposure of this eastern trace of the Cordelia fault was observed near the western abutment of an abandoned earthfill dam, based on field observations by this writer (locality 5, Figure 1). At the abandoned reservoir site is an exposure of an approximately 0.5 meter wide fault zone (N-S strike, near vertical dip). Possible shears in colluvium were seen in the northern side of this exposure. The upper part of this colluvial unit had been removed by grading. However, upon further inspection, it was decided that the shears were actually in weathered bedrock fault gouge. The entire colluvial section was preserved (with a crudely developed stoneline) on the southern side of this exposure. No shears were observed in this colluvial unit. Borchardt estimated the age of the colluvial unit as mid-Holocene, based on a lack of soil structure and clay films.

South of locality 5 the fault seems to be delineated by vague tonal lineaments in Holocene alluvium (Figure 1). These tonal lineaments may connect along a right stepping configuration with faults reported by Vahdani and others (1989).

The Cordelia fault north of locality 1 is delineated by a linear trough in bedrock, aligned saddles, and three right-laterally deflected drainages (Figure 1). Trenches excavated by Levish (1991) within the linear trough demonstrated the presence of a late Quaternary active fault that could have had minor Holocene surface fault rupture. However, faulting was not observed at the northernmost end of the trough.

North of the linear trough the Cordelia fault was presumed to lie within a saddle (locality 6, Figure 1). Continuous exposures of unfaulted ashflow tuff in the center of the saddle (just east of the inferred fault trace) eliminate this as a location for the fault. The ashflow tuff seems to be truncated high on the western side of this saddle; the linear contact strikes about N05°W . However, along the projection of the fault between this saddle and the linear trough to the south lie exposures of unfaulted ashflow tuff, based on field observations by this writer. The lack of a fault where expected in Levish's trench T-4 and the lack of unfaulted ashflow tuff to the north indicate that the Cordelia fault north of the linear trough is a discontinuous bedrock fault.

The scarp and right-laterally deflected drainages north of locality 6 seem isolated and may be erosional features along an older Quaternary fault (Figure 1). The deflected drainages are in bedrock and lack the youthfulness of ephemeral geomorphic features associated with recent faulting. Similarly, the east-facing scarp in bedrock is sinuous and discontinuous in detail and is most likely the result of differential erosion.

CONCLUSIONS

The Cordelia fault north of Highway 80 is moderately to locally well-defined in bedrock, but generally lacks ephemeral geomorphic features indicative of right-lateral strike-slip displacement in Holocene time (Figure 1). The moderately defined geomorphic expression and the apparent lack of faulting reported by Dever and Anderson (1978) just north of Highway 80 formed the basis for recommending against zoning the fault north of the highway (Bryant, 1981). However, an investigation by Vahdani and others (1990) demonstrated that Holocene displacement has occurred farther north than originally thought (Figure 1). Vague tonal lineaments in alluvium of probable Holocene age (Bates, 1977) (locality 4) are associated with faults reported by Vahdani and others.

Trenches excavated by Carey and Wigginton (1989) and the lack of a significant fault seen in nearly continuous exposures of bedrock at locality 3 suggest that a significant fault may not exist along the western trace of the Cordelia fault zone south of locality 1 as mapped by Helley and Herd (1977). However, a soil-filled fissure exposed in the Carey and Wigginton investigation is suggestive of minor Holocene fault rupture. It is possible that recent displacement has occurred along the Cordelia fault zone either discontinuously along this western trace, along the eastern trace, or is distributed along a broad zone bounded by the eastern and western traces (Figure 1). An undisturbed stoneline observed in the western abutment of an abandoned dam (locality 4) suggests that Holocene displacement is either minor or is lacking along this eastern branch of the Cordelia fault.

Trenching by Levish (1991) (Figure 1; Figures 2 and 3) neither proved nor disproved the existence of Holocene active faults just north of locality 1. A soil-filled fissure and the juxtaposition of bedrock against latest Pleistocene alluvium is suggestive of Holocene displacement. It is not clear if poorly defined stonelines, assumed to have formed about 9 ka, are or are not offset along the fault. However, most of these stonelines could not be traced across the fault, suggesting disruption along the fault. The offset A soil horizon reported by Helley and Herd (1977) was not verified, although lack of displacement of this weakly developed soil horizon does not preclude minor Holocene fault rupture. Continuity of the fault north of the linear trough was not verified, based on a trench exposure and field observations. It seems that late Pleistocene displacement along the Cordelia fault is discontinuous and poorly defined here.

The geomorphic expression of the Cordelia fault zone is consistent with late Quaternary right-lateral strike-slip displacement. Significant Holocene offset, indicated by small-scale ephemeral geomorphic features, is lacking along traces of the fault zone. However, trench investigations by Vahdani and others (1990), Cole and Pratt (1991), and Levish (1991) either demonstrated a degree of Holocene offset or could not prove a lack of Holocene offset. Thus, it seems reasonable to conclude that minor, distributive fault rupture has occurred along selected traces of the Cordelia fault during Holocene time.

RECOMMENDATIONS

Recommendations for zoning faults for special studies are based on the criteria of "sufficiently active" and "well-defined" (Hart, 1990).

The decision whether or not to recommend zoning for special studies traces of the Cordelia fault north of Interstate 80 is difficult because the evidence for or against recency along the fault is not compelling. However, trench data does indicate some degree of fault rupture potential for traces of the fault. Thus, it is recommended to zone for Special Studies traces of the Cordelia fault as shown on Figure 1 (Cordelia and Mt. George quadrangles, highlighted in yellow). Principal references cited should be Bryant (1981), Helley and Herd (1977), Vahdani and others, 1990, and Bryant (this report).

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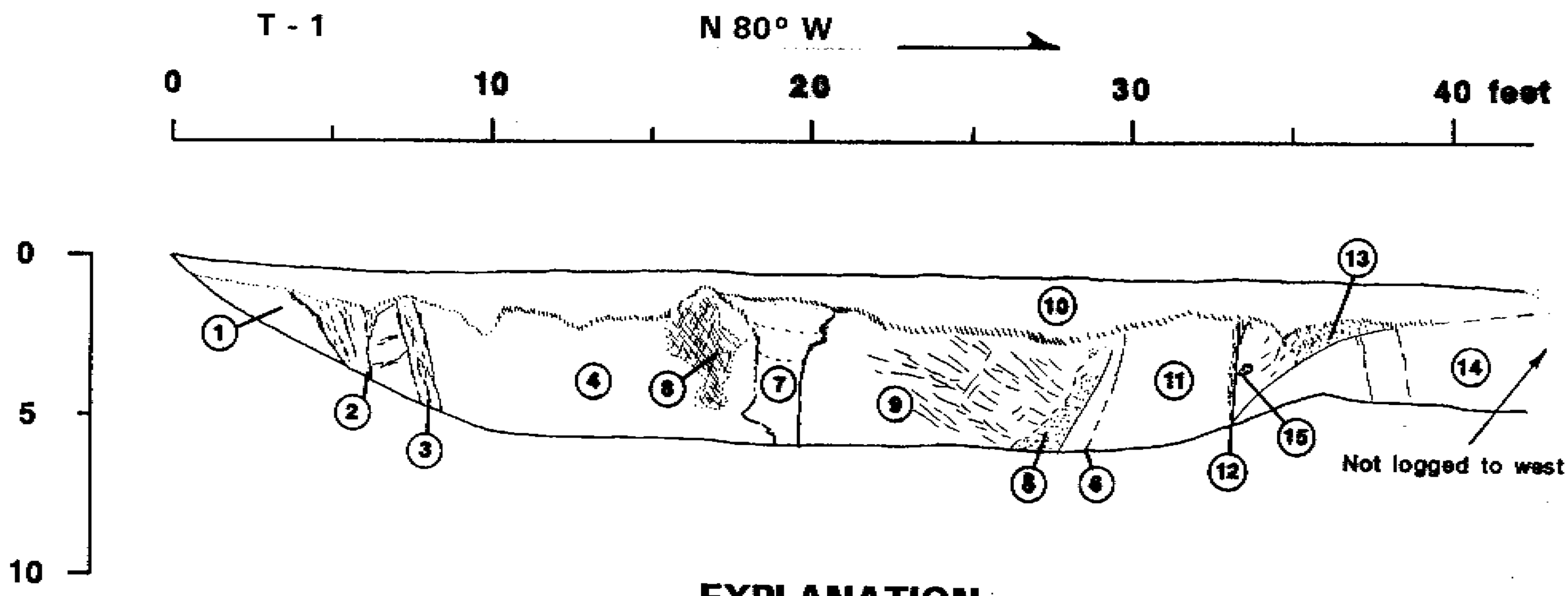


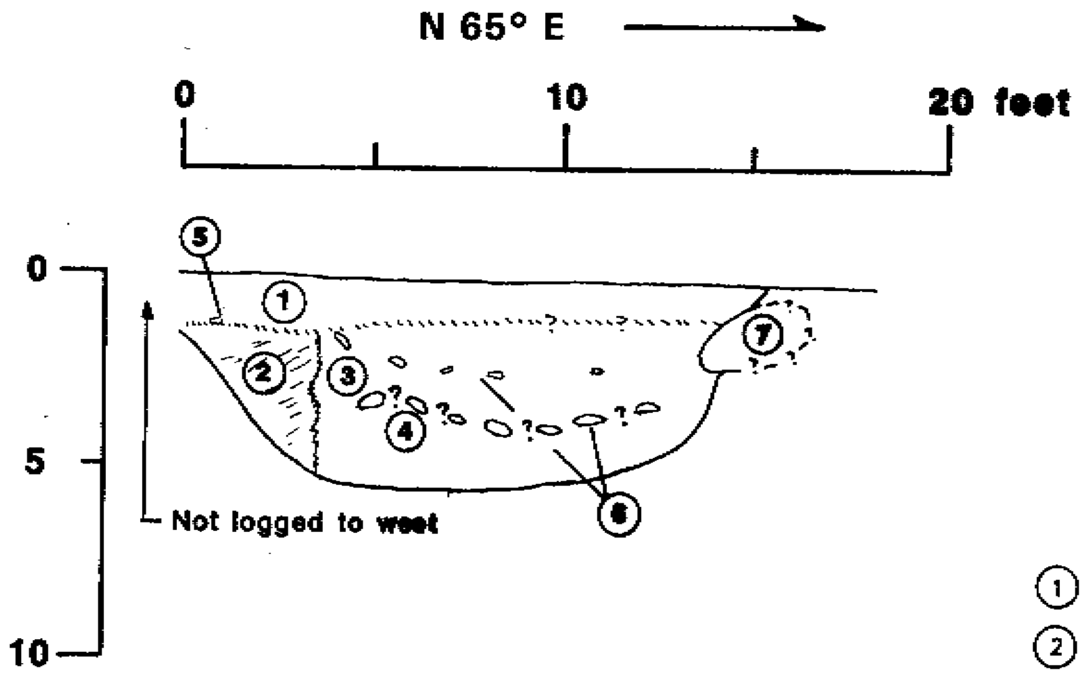
EXPLANATION

1. Medium gray ashflow tuff - relatively unfractured.
2. flt: N02°E 82°W
3. flt: N06°W 76°W - ≈1 cm gouge.
4. Slightly fractured ashflow tuff.
5. Loose soil fill or krotovina (?).
6. Shear: N05°W 62°E.
7. Soil-filled fissure along flt. plane. Borchardt described "micro-Bt" horizons within fissure fill that probably indicate a climatic drying pulse consistent with early Holocene climatic conditions. Soil filled fissure not present on north wall of trench; there was, however, a fault on strike that truncated bedrock units. No clear offset of the overlying A soil horizon, though this is a soil that probably has developed less than 5 ka, based on the weak A horizon development.
8. Root zone.
9. Strong fracturing in ashflow tuff. Dips about 17°W (apparent).
10. A horizon: sandy loam 10YR 6/2(d), 10YR 3/3.5(m).
11. Shear fabric in weathered and brecciated ashflow tuff.
12. flt: N05°W 82°E - truncates lt. gray tuff.
13. Weathered bedrock/soil tongue.
14. Light gray tuff - slightly fractured.
15. Krotovina.

Sketch by W. Bryant, 9/24/91

Figure 2 (Supplement #2 to FER-127). Sketch of trench T-1 excavated by Levish (1991).

T - 3B



EXPLANATION

1. Colluvium with weakly developed A horizon.
2. Fractured ashflow tuff.
3. Colluvial unit truncated against bedrock - no well-defined shears.
4. EBt horizon.
5. Poorly defined stoneline.
6. Stonelines.
7. Large boulder.

Sketch by W. Bryant, 9/24/91

Figure 3 (Supplement #2 to FER-127). Sketch of trench T-3b excavated by Levish (1991).