CALIFORNIA DIVISION OF MINES AND GEOLOGY

FAULT EVALUATION REPORT FER-142

November 17, 1982

1. Name of faults: Little Salmon and Yager faults, Humboldt County.

2. Location of faults: Fields Landing, Fortuna, Hydesville, Owl Creek, Redcrest, and Bridgeville 7.5-minute quadrangles (Figure 1).

3. Reason for evaluation: Part of a state-wide program to evaluate faults for recency of movement (see Hart, 1980).

4. References:

Coppersmith, K.J., October 1980, Appendix B, Summary of exploration locality investigation, in Woodward-Clyde Consultants, Evaluation of the potential for resolving the geologic and seismic issues at the Humboldt Bay Power Plant Unit Number 3: Unpublished consulting report prepared for Pacific Gas and Electric Company, 107 p.

Jennings, C.W., 1975, Fault map of California with locations of volcanoes, thermal springs, and thermal wells: California Division of Mines and Geology, Geologic Data Map No. 1, scale 1:750,000.

Kelsey, H.M., and A.O. Allwardt, 1974, Geologic map of the Van Duzen River Basin, Humboldt and Trinity Counties, California, in California Department of Water Resources, Van Duzen River Basin Environmental Atlas, plate 8, 10 sheets, scale 1:35,200.

Ogle, B.A. 1953, Geology of the Eel River Valley area, Humboldt County, California: California Division of Mines Bulletin 164, 128 p., 6 plates, scale 1:62,500.

Turcotte, T., L. Hutchings, R. Simon, and P. Somerville, October 1980, Appendix D, Summary of seismicity investigations, in Woodward-Clyde Consultants, Evaluation of the potential for resolving the geologic and seismic issues at the Humboldt Bay Power Plant Unit Number 3: Unpublished consulting report prepared for Pacific Gas and Electric Company, 145 p.

U.S. Department of Agriculture, 1954, Black and white aerial photographs, CVL series, roll 7N, numbers 81-82, 93-94, 168-169, and roll 9N, numbers 127-130 scale 1:20,000.

U.S. Geological Survey, 1972, Black and white aerial photographs, GS-VCZP series, roll 3, numbers 97-102, 116-120, 147-151, and 160-163, scale 1:31,500.

Wagner, J.R., October 1980, Appendix A, Summary of regional stratigraphy and geologic structure, in Woodward-Clyde Consultants, Evaluation of the potential for resolving the geologic and seismic issues at the Humboldt

Bay Power Plant Unit Number 3: Unpublished consulting report prepared for Pacific Gas and Electric Company, 73 p.

Woodward-Clyde Consultants, October 1980, Appendix C. Summary of plant site investigations, in Woodward-Clyde Consultants, Evaluation of the potential for resolving the geologic and seismic issues at the Humboldt Bay Power Plant Unit Number 3: Unpublished consulting report prepared for Pacific Gas and Electric Company, 145 p.

5. Summary of available data:

The Little Salmon and Yager faults first mapped by Ogle (1953), were described as a northwest-trending system of Cenozoic reverse or thrust faults (Figures 2A, 2B and 2C). On his map, Ogle indicates that the Little Salmon fault extends from Fields Landing southeastward to and beyond its junction with the Yager fault. On his cross-sections, however, Ogle refers to the "Yager-Little Salmon fault" northwest of the point where the two bifurcate.

Ogle estimated that as much as 10,000 feet of vertical slip may have occurred along the Little Salmon fault near Hydesville. In the vicinity of Fields Landing, he shows about 2,000 feet of vertical-slip displacement along the Yager-Little Salmon fault (he refers to this amount of slip as negligible). Based on Ogle's map, it appears that the Little Salmon fault truncates late Pleistocene deposits (Hookton Formation). It is clear that Ogle concluded that the Little Salmon-Yager fault system may have been active during the Holocene, although he seems to have based this conclusion partly, if not wholly, on the apparent "need" for a triggering mechanism for several major debris flow failures, evidence of which he noted nearby.

The only other original mapping of the Little Salmon and Yager faults is that of Kelsey and Allwardt (1974). Their maps, however, have no accompanying text and provide no additional data on post-Carlotta (late Quaternary) movement. All other works appear to mostly be compilations, with perhaps some minor revisions, of Ogle (1953) and Kelsey and Allwardt (1974) In essence, almost all of the later work has been directed more at determining the history of movement along the Little Salmon and Yager faults than at determining whether the faults are accurately mapped.

In the late 1970's, Woodward-Clyde Consultants was hired to investigate the tectonic relationships of the faults in the vicinity of the PG & E nuclear power plant located at Fields Landing. Several deep boreholes were drilled in an effort to learn more about the faults. Based on the borehole data, Woodward-Clyde (1980) concluded that the Little Salmon fault dips about 30° NE near Fields Landing. They also concluded, based on the apparent lesser offsets of progressively younger units, that repeated movement has taken place on the Little Salmon fault during late Quaternary time. Specifically, it appears that repeated movement has taken place since the beginning of deposition of the Hookton Formation (600,000 ± 100,000 ybp). The apparent dipslip offset of the top of the Hookton Formation is about 360 m. Since the top of the Hookton is 160,000 ± 40,000 years old, it appears that the Little Salmon fault has been moving at a rate of about 2.4 ± 0.6 mm/yr in the Fields

Landing area. Woodward-Clyde also concluded that the Bay Entrance fault is probably a splinter of the Little Salmon based on similar sense of subsurface offsets (east side up) and geometric relationships. Neither of these faults is exposed at the surface in the area where the subsurface data was collected, however (Woodward-Clyde Consultants, 1980).

To the south of the power plant site, Woodward-Clyde attempted to trench the Little Salmon fault (Coppersmith, 1980). On Humboldt Hill, near the boundary of Sections 20 and 29, two trenches were excavated and logged (Figures 3 and 4). The oldest faulted unit exposed in the trenches was the Rio Dell Formation (Plio-Pleistocene in age.) However, Coppersmith states that he was unable to determine what the overlying materials (units 2 and 3 on the trench logs) were. He states unit 3 could have been Rio Dell Formation, bay deposits, or colluvium, while unit 2 was either basal Hookton or terrace deposits. The age of the abrasion platform (top of unit 1) and the overlying deposits could not be estimated. However, a distinct pattern of conjugate shears was exposed in the trenches. The abrasion platform (top of unit 1 and/or 3) was offset about 5 to 7 m, with about 3.5 m of apparent offset on a single surface (see Figure 4). Coppersmith states that the terrace surface constrains the post-terrace displacement to less than 1 to 2 m; however, this investigator finds no such evidence to support such a conclusion since unit 3 in Figure 4 could be Rio Dell Formation. If this is the case, then the post-terrace displacement could be greater . The trench logs indicate that the base of the colluvium was displaced in one location; unfortunately, the soil and colluvium were not logged over much of the length of the trenches (Figure 3).

Coppersmith (1980) also examined a roadcut located just west of these two trenches. Although he did not describe what he saw, he stated that the Rio Dell clays appear to have been thrust several tens of meters over "sands of uncertain stratigraphic position that may be Hookton deposits." This suggests that the faults detected in the trenches described above are not the principal fault in the Salmon-Yager fault zone.

About 3/4 km to the southeast, two more trenches were excavated (Figure 5). Coppersmith (1980) reported that a distinct pattern of conjugate shears, similar to those found to the northwest, was present at this site, as well. The faults observed had dips of 30° to 50° NE and SW with slickensides indicating nearly pure dip-slip movement (rakes of 80° to 90°). Coppersmith states (p. B-82) that the contact between the Hookton Formation and the overlying colluvium was displaced about 2 m along a narrow zone of thrust faults. Unfortunately, he gives no clues in the text or the trench logs whether units 1, 2, or 3 (Figure 5) are Hookton or colluvium. This investigator suspects that units 1 and 2 are Hookton and unit 3 is colluvium, but the presence of clayey interbeds in unit 3 raises some doubt.

Woodward-Clyde (1980) also contains a summary of the data relating to late Quaternary faults at the PG & E power plant site. Based on an extensive borehole program and limited trenching, they concluded that there was no evidence that faulting had occurred at the plant site during the last 37,000 years. Similarly, they concluded that the north-dipping Buhne Point fault has not been active during at least the last 37,000 years. They base this conclusion on their observations that a stratigraphic unit is not offset and that this unit is overlain by younger units, one of which has been radiometrically dated by C^{14} methods as older than 37,000 years.

6. Seismicity:

The Humboldt County area has a long history of known seismic activity. Unfortunately, until 1974, when Tera Corporation installed a 16-station microseismic network, the limited number of seismographs in northwestern California precluded the determination of focal depths or the precise locations of epicenters (Turcotte, et al., 1980). Considering the northwestern dip of the Little Salmon fault, it is conceivable that the 1954 (M6.5) earthquake may have occurred either on the Little Salmon-Yager fault system or on the Mad River fault zone.

The detailed studies by Tera rather strongly suggest that subduction is occurring beneath the area. It appears that the primary zone of this subduction is about 15 to 30 km beneath the surface near Ferndale, and that some secondary faulting is occurring locally in the upper crustal plate (Figure 6). First motion studies do not clearly support this hypothesis, however (Turcotte, et al., 1980).

7. Field and Air Photo Data:

U.S. Geological Survey and U.S. Department of Agriculture aerial photographs were reviewed in an effort to detect features indicative of recent faulting. Well-defined features that offer definitive evidence in support of Holocene displacement along the Little Salmon and Yager faults were not evident on the photos. However, features suggestive (permissive) of recent movement are locally present. For example, north of Hydesville (Figure 7B), the mapped trace of the Little Salmon fault generally coincides with a general, south-facing escarpment that is also coincident with the abrupt termination of the late Pleistocene terraces. Also, Strongs and Yager Creeks lack terraces along their courses north of the fault, but have sizeable floodplains south of the fault. This suggests that the area north of the Little Salmon has been substantially and progressively elevated relative to the area to the south of the fault. Northwest of Rohner Creek, however, it is difficult to tell just where the fault is located.

East of Yager Creek, bedding is locally fairly obvious. Apparent truncations of the beds visible on the photos suggest that the geology is mismapped and that faulting is much more complex than shown by Ogle (1953) and Kelsey and Allwardt (1974).

Several large landslides are apparent in the area near the College of the Redwoods (Figure 6A). North of the campus, Humboldt Hill appears to be coming apart (spreading laterally) as evidenced by numerous scarps and troughs. If this is the case, then some of the features identified in their trenches by Coppersmith (1980) could have resulted from recent landslide movements along older faults. Such landsliding also makes precise location of the Little Salmon fault extremely difficult.

Due to limited time and funding, only a brief reconnaissance of the area was performed. Exposures of the faults investigated in this FER were not found. The filled trench sites summarized by Coppersmith were visited, but no new data relevant to the question of zoning was obtained.

8. Conclusions:

The data available on the Little Salmon and Yager faults appears curiously mixed. All workers (Ogle, 1953; Coppersmith, 1980; Kelsey and Allwardt, 1974) agree that the Little Salmon is a reverse or thrust fault that has been active during the Quaternary. Coppersmith concluded that the Little Salmon has been active in the last 160,000 ± 40,000 years since the top of the Hookton Formation is apparently offset. Coppersmith also concluded that post-Hookton colluvium has been faulted. The age of this colluvium has not been established, but is certainly latest Quaternary and might be Holocene. Therefore, it appears that latest Quaternary (possibly Holocene) activity has been demonstrated on some branch faults in the Little Salmon-Yager fault zone.

The Little Salmon fault does not appear to be well-defined over much of its length. The location of the principal trace is inferred near the College of the Redwoods, based on trench data. Similarly, the location of the fault across Tompkins Hill appears to be based largely on subsurface data. The difficulty in distinguishing between sediments of the Hookton Formation and the Wildcat Group makes field mapping difficult (Wagner, 1980). Finally, north of Carlotta, it appears that the fault zone is more complex than shown by Ogle (1953), based on the aerial photos interpreted.

9. Recommendations:

Based on the information contained herein, the Little Salmon and Yager faults should not be zoned at this time. Data in support of Holocene fault movement is inconclusive, and this investigator suspects that the fault is more complex than shown. Given the current standard width of a Special Studies Zone (1/4 mile or less), it is likely that the principal fault may lie outside of any zone established using the existing geologic maps. It is quite possible that the Little Salmon fault and/or the Yager fault may be active. Therefore, given these concerns and the paucity of data, further work is recommended when time and funding permits.

I agree with the recommendations. EWH 12/13/82

Theodore C. Smith

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November 17, 1982

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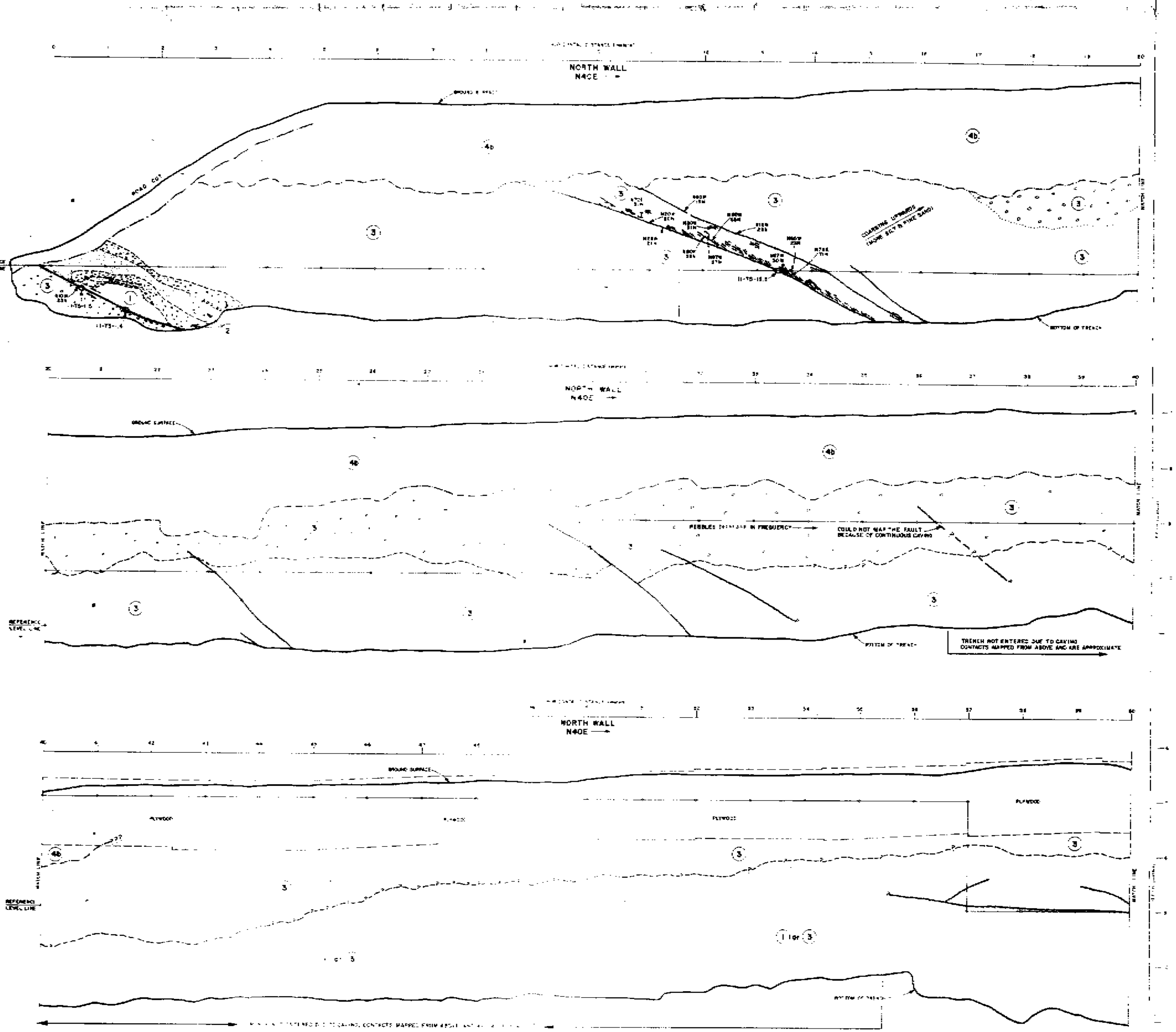


FER-142. Figure 3, sheet 1 (from Coppersmith, 1980).

LITHOLOGIC DESCRIPTIONS
BRAZIL PROPERTY TRENCH LOGS
11–T5a & 11–T5b

Unit 4: Soil

4a: A/B contact

4b: Base of colluvium; grades downslope to 4a.

Unit 3: Silty clay and silty clay with random pebbles. (colluvium, bay deposits, or Rio Dell Fm)
Light gray (2.5 Y N7/ and 2.5 Y N7/2 moist) mottled with reddish yellow (7.5 YR 6/8 moist) silty clay with fine to coarse sand and occasional subangular to subrounded pebbles (2 mm–5 cm, mode 1 cm).

Unit 2: Interbedded pebbles and sand (terrace deposits or basal Hookton Fm)
Light gray (7.5 YR N7/ moist), reddish yellow (7.5 YR 6/8 moist) and strong brown (7.5 YR 5/6 moist) pebbles and sand; pebbles (3 mm–4 cm, mode 6 mm) are subangular to subrounded, 90 percent chert, 8 percent quartz and 2 percent metamorphic rock and sandstone in a fine- to coarse-grained sand matrix; interbedded sands are subrounded and moderately sorted with occasional pebbles; thicknesses of sand interbeds range from 1 cm to 1 m; some cross-bedding.

Unit 1: Rio Dell Formation

Light gray (2.5 Y N7/ moist) mottled with reddish yellow (2.5 YR 6/8 moist) silty clay with minor fine to medium sand grains.

EXPLANATION

Lithologic Contact; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm.

Soil Contact

Disturbed Soil Contact

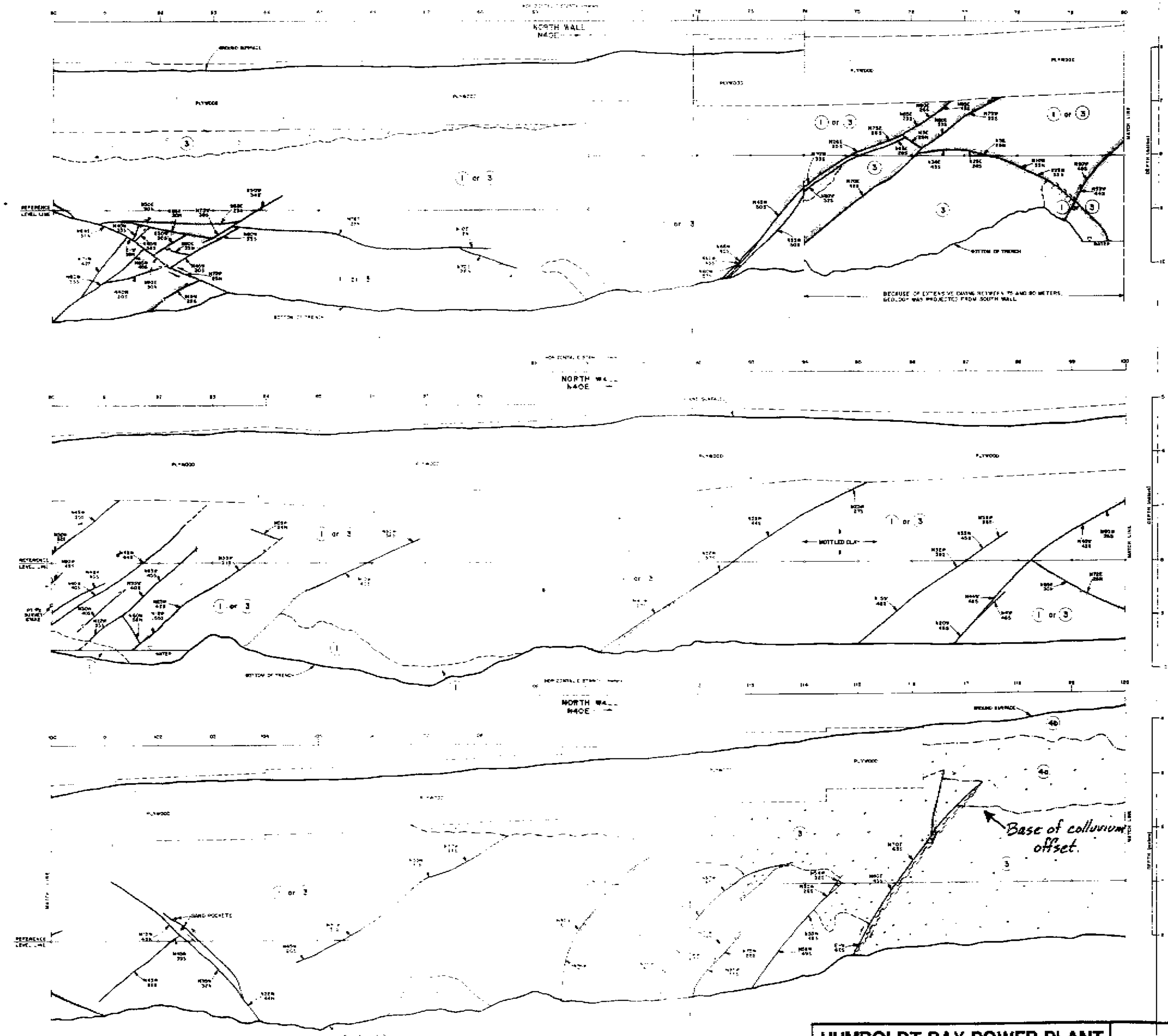
N75W 60N — Fault; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative movement.

N70W 55N — Strike and Dip of jointing

Shears

HUMBOLDT BAY POWER PLANT UNIT No. 3	BRAZIL PROPERTY EXPLORATION LOCALITY TRENCH LOG 11–T5a	13976G–6512 B-50a
Woodward-Clyde Consultants		Figure B–33a

FER-142. Figure 3, sheet 2 (from Coppersmith, 1980).



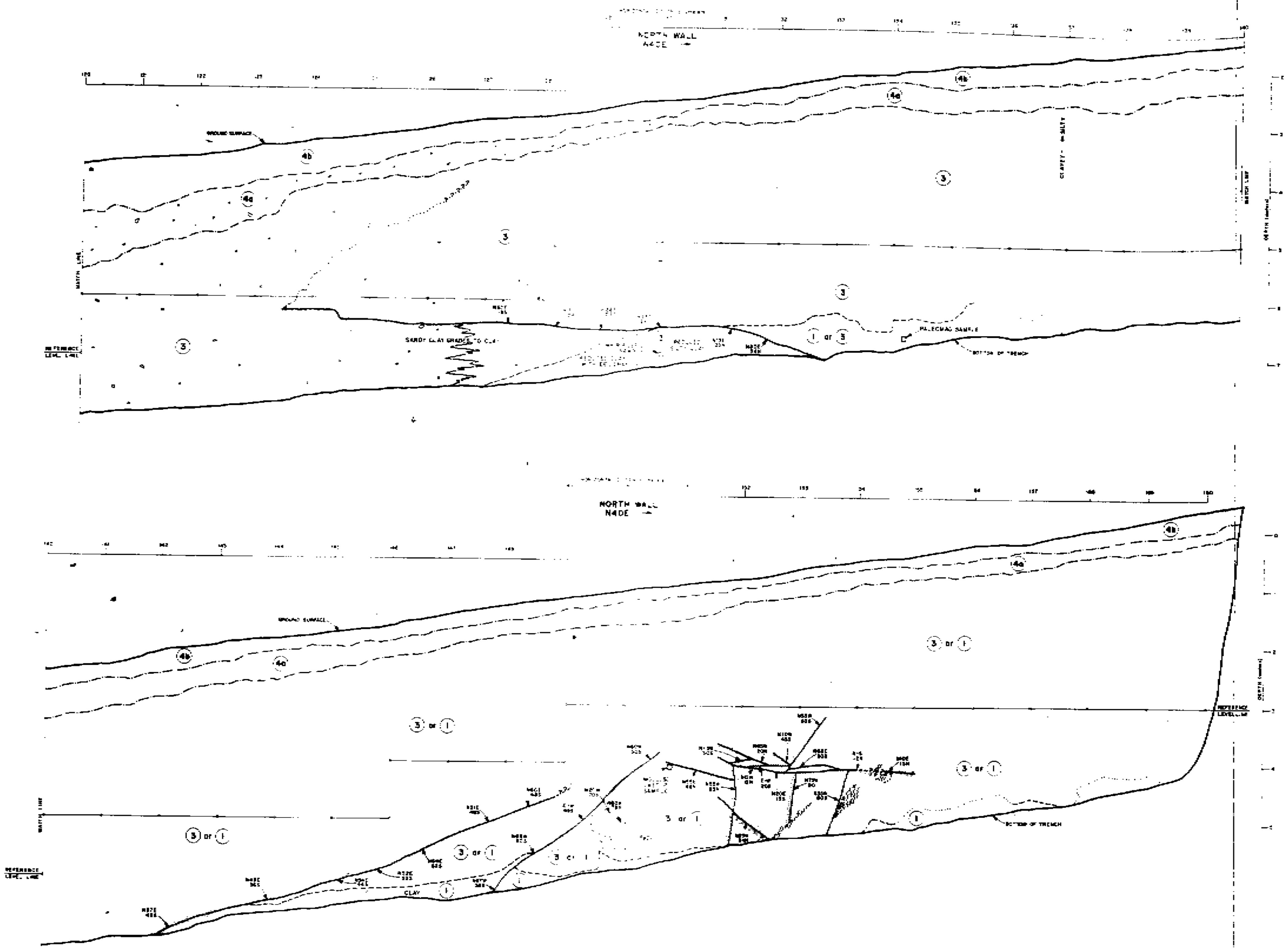
NOTE:
See Figure B–33a for Lithologic Descriptions

EXPLANATION

- Lithologic Contact; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm.
- Soil Contact
- Disturbed Soil Contact
- N75W 60N — Fault; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative movement.
- N70W 55N — Strike and Dip of jointing
- Shears

HUMBOLDT BAY POWER PLANT UNIT No. 3	BRAZIL PROPERTY EXPLORATION LOCALITY TRENCH LOG 11–T5a	13976G–6512 B-50b
Woodward-Clyde Consultants		Figure B–33b

FER-142. Figure 3, sheet 3 (from Coppersmith, 1980).



NOTE:
See Figure B–33a for Lithologic Descriptions

EXPLANATION

Lithologic Contact; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm.

Soil Contact

Disturbed Soil Contact

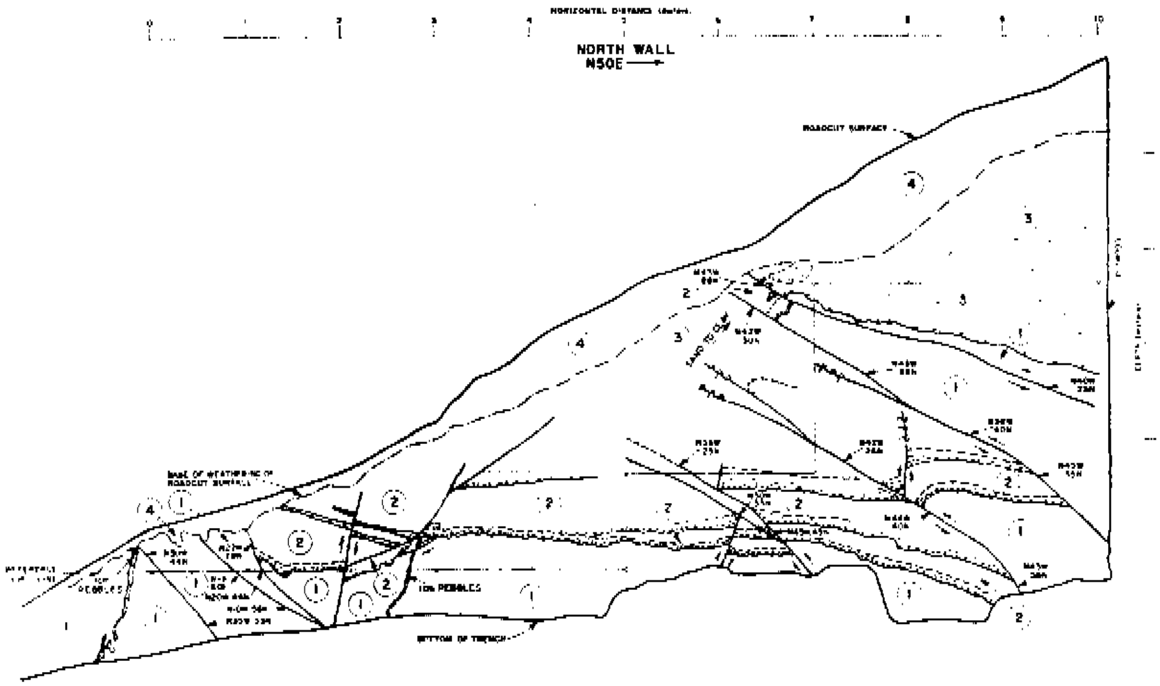
Fault; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative movement. (N75W 60N)

N70W 55N Strike and Dip of jointing

Shears

HUMBOLDT BAY POWER PLANT UNIT No. 3	BRAZIL PROPERTY EXPLORATION LOCALITY TRENCH LOG 11–T5a	13976G–6512 B-50c
Woodward-Clyde Consultants		Figure B–33c

FER-142. Figure 4 (from Coppersmith, 1980).



NOTE:
See Figure B–33a for Lithologic Descriptions

EXPLANATION

Lithologic Contact; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm.

Soil Contact

Disturbed Soil Contact

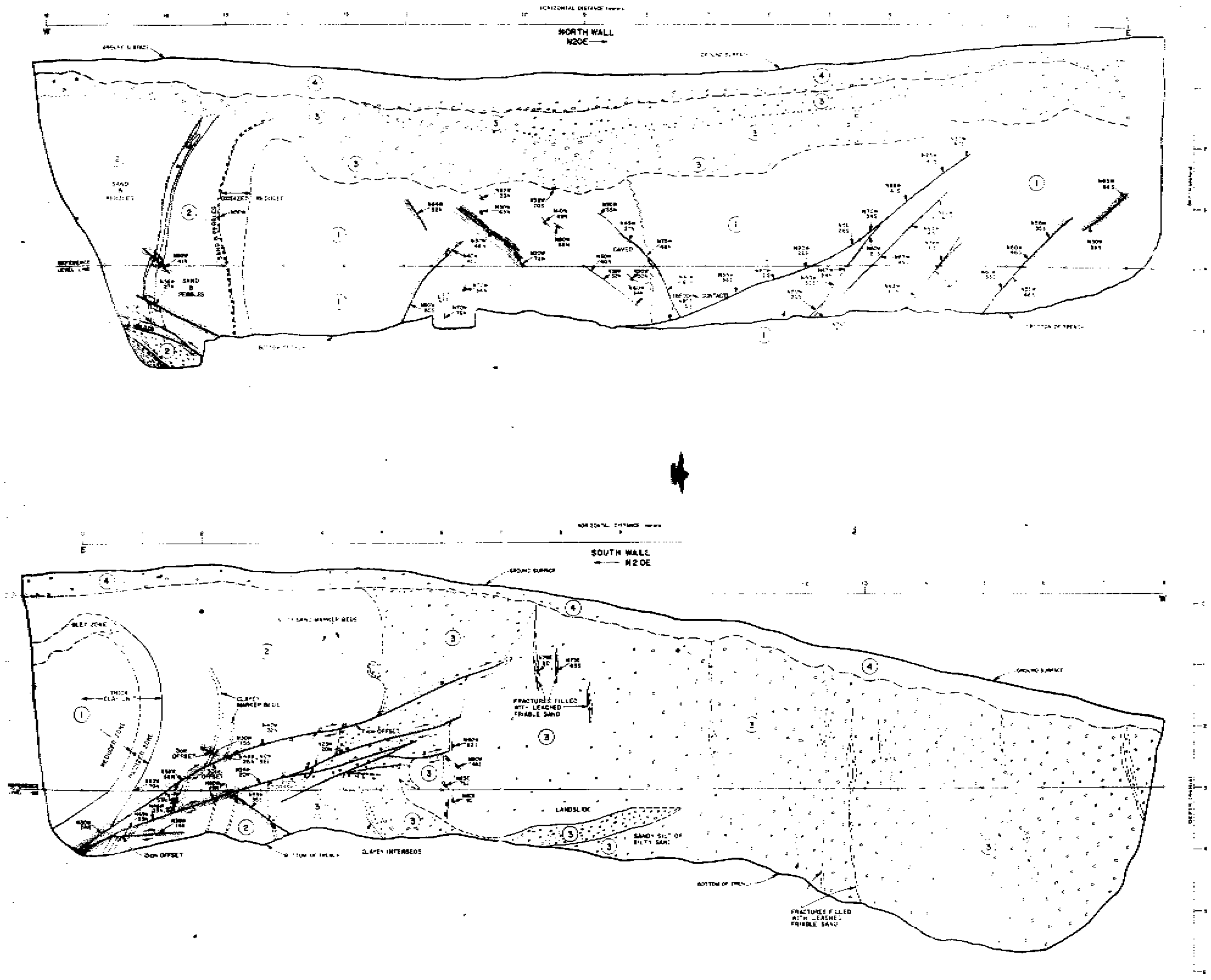
N75W 60N — Fault; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative movement.

N70W 55N — Strike and Dip of jointing

Shears

HUMBOLDT BAY POWER PLANT UNIT No. 3	BRAZIL PROPERTY EXPLORATION LOCALITY TRENCH LOG 11–T5b	13976G–6512 B-50d
Woodward-Clyde Consultants		Figure B–33d

FER-142. Figure 5 (from Coppersmith, 1980).



LITHOLOGIC DESCRIPTIONS
COLLEGE OF THE REDWOODS TRENCH LOGS
11–T4a & 11–T4b

Unit 4: Soil
Strong brown (7.5 YR 4/6 moist), non-sticky, non-plastic, firm loamy sand; moderately developed crumb to granule ped structure.

Unit 3: Sand and gravel
Yellowish brown (10 YR 5/6 moist) fine sand to cobbles; subangular to well rounded; poorly sorted; slightly indurated.

Unit 2: Interbedded silt and pebbles: *terrace deposits or Hookton F*
Brownish yellow (10 YR 6/8 moist) silt interbedded with large subangular to well rounded pebbles of approximately 70 percent chert, 5 percent quartz. Thicknesses of individual silt or pebble beds are approximately 3 cm to 20 cm.

Unit 1: Clay: *Rio Dell Formation*
Gray (7.5 YR N5/ moist) to bluish gray (5B 5/1 moist), very sticky, very plastic clay; minor silt and sand; portions near surface are gleyed to light gray (7.5 YR N7/ moist).

EXPLANATION

Lithologic Contact; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm.

Soil Contact

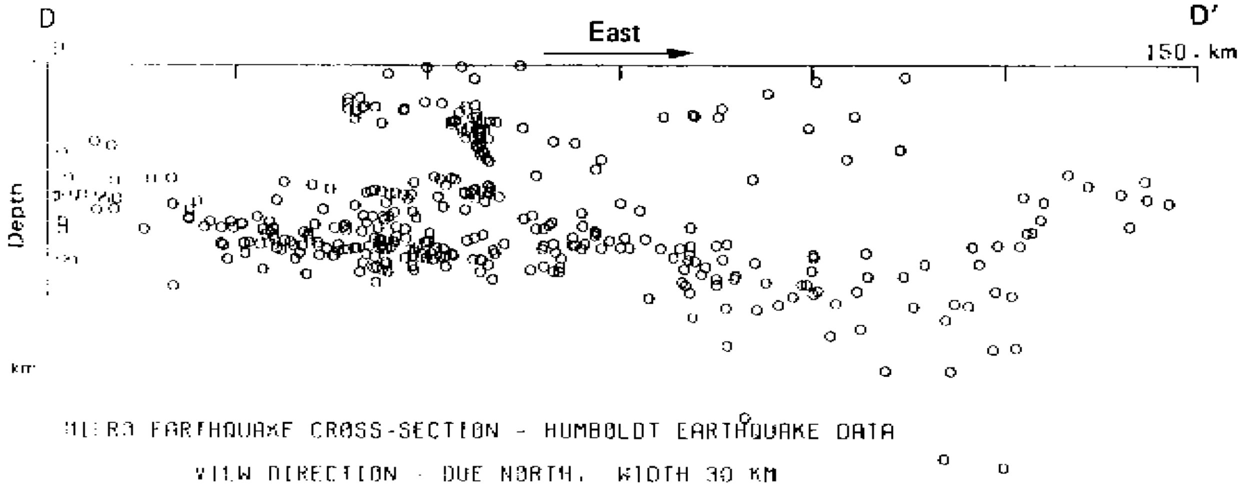
Disturbed Soil Contact

N75W 60N — Fault; solid line where resolution is less than 2 cm, dashed line where 2–5 cm, dotted line where 5–15 cm; strike and dip of fault plane indicated; arrows indicate sense of relative movement.

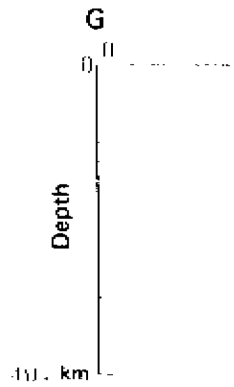
N70W 55N — Strike and Dip of jointing

Shears

HUMBOLDT BAY POWER PLANT UNIT No. 3	COLLEGE OF THE REDWOODS EXPLORATION LOCALITY TRENCH LOGS 11–T4a & 11–T4b	13976G–6512 B-49
Woodward-Clyde Consultants		Figure B–29



MICRO EARTHQUAKE CROSS-SECTION - HUMBOLDT EARTHQUAKE DATA
VIEW DIRECTION - DUE NORTH. WIDTH 30 KM
CENTERED AT 40.77N. 124.00W



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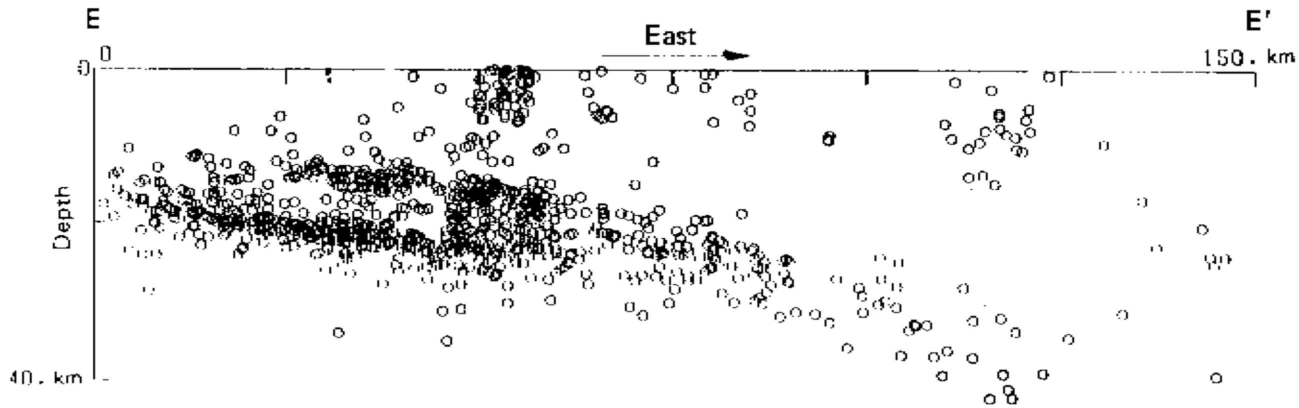

MICRO-EARTHQUAKE CROSS-SECTION - HUMBOLDT EARTHQUAKE DATA
VIEW DIRECTION - DUE NORTH. WIDTH 30 KM
CENTERED AT 40.50N. 124.00W

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FER-142. Figure 6. Micro-earthquake cross-section (from Turcotte, et al., 1980).