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A Report Prepared for:

Lawrence Berkeley National Laboratory
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Attention: Mr. Henry Martinez
Senior Project Manager

FAULT INVESTIGATION COMPUTATION RESEARCH AND THEORY BUILDING LAWRENCE BERKELEY NATIONAL LABORATORY BERKELEY, CALIFORNIA

Kleinfelder Job No.: 67929

By

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Important Information About Your

Geotechnical Engineering Report

Subsurface problems are a principal cause of construction delays, cost overruns, claims, and disputes.

The following information is provided to help you manage your risks.

Geotechnical Services Are Performed for Specific Purposes, Persons, and Projects

Geotechnical engineers structure their services to meet the specific needs of their clients. A geotechnical engineering study conducted for a civil engineer may not fulfill the needs of a construction contractor or even another civil engineer. Because each geotechnical engineering study is unique, each geotechnical engineering report is unique, prepared *solely* for the client. No one except you should rely on your geotechnical engineering report without first conferring with the geotechnical engineer who prepared it. *And no one — not even you* — should apply the report for any purpose or project except the one originally contemplated.

Read the Full Report

Serious problems have occurred because those relying on a geotechnical engineering report did not read it all. Do not rely on an executive summary. Do not read selected elements only.

A Geotechnical Engineering Report Is Based on A Unique Set of Project-Specific Factors

Geotechnical engineers consider a number of unique, project-specific factors when establishing the scope of a study. Typical factors include: the client's goals, objectives, and risk management preferences; the general nature of the structure involved, its size, and configuration; the location of the structure on the site; and other planned or existing site improvements, such as access roads, parking lots, and underground utilities. Unless the geotechnical engineer who conducted the study specifically indicates otherwise, do not rely on a geotechnical engineering report that was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

Typical changes that can erode the reliability of an existing geotechnical engineering report include those that affect:

- the function of the proposed structure, as when it's changed from a parking garage to an office building, or from a light industrial plant to a refrigerated warehouse,
- elevation, configuration, location, orientation, or weight of the proposed structure,
- composition of the design team, or
- project ownership.

As a general rule, *always* inform your geotechnical engineer of project changes—even minor ones—and request an assessment of their impact. *Geotechnical engineers cannot accept responsibility or liability for problems that occur because their reports do not consider developments of which they were not informed.*

Subsurface Conditions Can Change

A geotechnical engineering report is based on conditions that existed at the time the study was performed. *Do not rely on a geotechnical engineering report* whose adequacy may have been affected by: the passage of time; by man-made events, such as construction on or adjacent to the site; or by natural events, such as floods, earthquakes, or groundwater fluctuations. *Always* contact the geotechnical engineer before applying the report to determine if it is still reliable. A minor amount of additional testing or analysis could prevent major problems.

Most Geotechnical Findings Are Professional Opinions

Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. Geotechnical engineers review field and laboratory data and then apply their professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ—sometimes significantly—from those indicated in your report. Retaining the geotechnical engineer who developed your report to provide construction observation is the most effective method of managing the risks associated with unanticipated conditions.

A Report's Recommendations Are *Not* Final

Do not overrely on the construction recommendations included in your report. *Those recommendations are not final,* because geotechnical engineers develop them principally from judgment and opinion. Geotechnical engineers can finalize their recommendations only by observing actual subsurface conditions revealed during construction. *The geotechnical engineer who developed your report cannot assume responsibility or liability for the report's recommendations if that engineer does not perform construction observation.*

A Geotechnical Engineering Report Is Subject to Misinterpretation

Other design team members' misinterpretation of geotechnical engineering reports has resulted in costly problems. Lower that risk by having your geotechnical engineer confer with appropriate members of the design team after submitting the report. Also retain your geotechnical engineer to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering report. Reduce that risk by having your geotechnical engineer participate in prebid and preconstruction conferences, and by providing construction observation.

Do Not Redraw the Engineer's Logs

Geotechnical engineers prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering report should *never* be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, *but recognize that separating logs from the report can elevate risk.*

Give Contractors a Complete Report and Guidance

Some owners and design professionals mistakenly believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering report, *but* preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with the geotechnical engineer who prepared the report (a modest fee may be required) and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. *Be sure contractors have sufficient time* to perform additional study. Only then might you be in a position to give contractors the best information available to you, while requiring them to at least share some of the financial responsibilities stemming from unanticipated conditions.

Read Responsibility Provisions Closely

Some clients, design professionals, and contractors do not recognize that geotechnical engineering is far less exact than other engineering disciplines. This lack of understanding has created unrealistic expectations that have led to disappointments, claims, and disputes. To help reduce the risk of such outcomes, geotechnical engineers commonly include a variety of explanatory provisions in their reports. Sometimes labeled "limitations" many of these provisions indicate where geotechnical engineers' responsibilities begin and end, to help others recognize their own responsibilities and risks. *Read these provisions closely.* Ask questions. Your geotechnical engineer should respond fully and frankly.

Geoenvironmental Concerns Are Not Covered

The equipment, techniques, and personnel used to perform a *geoenvironmental* study differ significantly from those used to perform a *geotechnical* study. For that reason, a geotechnical engineering report does not usually relate any geoenvironmental findings, conclusions, or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. *Unanticipated environmental problems have led to numerous project failures.* If you have not yet obtained your own geoenvironmental information, ask your geotechnical consultant for risk management guidance. *Do not rely on an environmental report prepared for someone else.*

Obtain Professional Assistance To Deal with Mold

Diverse strategies can be applied during building design, construction, operation, and maintenance to prevent significant amounts of mold from growing on indoor surfaces. To be effective, all such strategies should be devised for the *express purpose* of mold prevention, integrated into a comprehensive plan, and executed with diligent oversight by a professional mold prevention consultant. Because just a small amount of water or moisture can lead to the development of severe mold infestations, a number of mold prevention strategies focus on keeping building surfaces dry. While groundwater, water infiltration, and similar issues may have been addressed as part of the geotechnical engineering study whose findings are conveyed in this report, the geotechnical engineer in charge of this project is not a mold prevention consultant; ***none of the services performed in connection with the geotechnical engineer's study were designed or conducted for the purpose of mold prevention. Proper implementation of the recommendations conveyed in this report will not of itself be sufficient to prevent mold from growing in or on the structure involved.***

Rely, on Your ASFE-Member Geotechncial Engineer for Additional Assistance

Membership in ASFE/The Best People on Earth exposes geotechnical engineers to a wide array of risk management techniques that can be of genuine benefit for everyone involved with a construction project. Confer with you ASFE-member geotechnical engineer for more information.

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TABLE OF CONTENTS

PLATES

FAULT INVESTIGATION
COMPUTATION RESEARCH AND THEORY BUILDING
LAWRENCE BERKELEY NATIONAL LABORATORY
BERKELEY, CALIFORNIA

1.0 INTRODUCTION

This report presents the results of Kleinfelder's fault investigation for the proposed Computation Research and Theory Building (CRT) located on the Lawrence Berkeley National Laboratory (LBNL) campus in Berkeley, California (Plate 1). The objective of this report is to provide LBNL with geologic information regarding the possible presence of active trace(s) of the Hayward fault on this site. This revised report incorporates peer review comments by William Lettis and Associates (WLA 7/3/08) and Preston Jordan (Engineering Geologist, Lawrence Berkeley National Laboratory (LBNL), 8/14/08). This revised report supersedes our original report dated 9/27/06.

1.1 LOCATION AND SITE DESCRIPTION

The CRT site is located on the west-facing slope, west of (below) Building 70A and east of (above) the Blackberry Gate entrance on the LBNL campus in Berkeley, California (see Site Location, Plate 1). No improvements or structures currently exist on the site. Current inclinations on the slope range from 1.5H:1V (horizontal: vertical) to 3H:1V.

The site is located within a state-mandated Earthquake Fault Zone, as defined by the California Geological Survey (CGS, 1982, formerly the California Division of Mines and Geology, CDMG) in accordance with the Alquist-Priolo Earthquake Fault Zone Act of 1972. It is our understanding that the property of LBNL does not fall under that jurisdiction of the State of California requiring a fault investigation; however, a fault study is standard practice for LBNL when the site is located in an Earthquake Fault Zone.

The mapped trace of the Hayward fault, as per the CGS (1982, Richmond, Oakland East and Oakland West), is located approximately 300 feet west of the site.

1.2 PROJECT DESCRIPTION

It is our understanding that the proposed 50,000-square-foot (footprint) new CRT building will be eight stories (stair-stepped up the slope) with the lowest level at approximately elevation 637 feet and the upper entrance deck at elevation 760 feet. The building will be cut into the hillside and retaining walls will be required along the east side of the building. Additional details of the planned development are not known at this time. If actual project considerations differ significantly from those indicated herein, we should be contacted to review and, if necessary, revise our recommendations.

1.3 PURPOSE AND SCOPE OF SERVICES

The purpose of this investigation is to evaluate the site for the possible presence of active faulting. The scope of services included the following:

- Excavation and logging of two fault trenches.
- Review of published geologic maps, aerial photographs, and literature from our files.
- Review of consultant's geologic and fault report from our files and on file with the CGS.
- Analysis of the collected data.
- Preparation of this report.

1.4 AUTHORIZATION

This investigation was authorized by LBNL in the Subcontractor Agreement number 6805923 signed by Laura Crosby of LBNL and Michael Burns of Kleinfelder, Inc.

2.0 GEOLOGIC SETTING

2.1 REGIONAL GEOLOGY

The site is located in the Berkeley Hills area within the Coast Range Geomorphic Province of Northern California. This province is generally characterized by northwest trending mountain ranges and intervening valleys, which are a reflection of the dominant northwest structural trend of the bedrock in the region. The basement rock in the northern portion of this province is presumed to consist of the Franciscan Complex, a diverse group of igneous, sedimentary, and metamorphic rocks of Upper Jurassic to Cretaceous age (140 to 65 million years old). The Franciscan Complex is part of a northwest trending belt of material immediately adjacent to the eastern edge of the San Andreas fault system, which is located approximately 30 kilometers west of the site. In the site vicinity, the Franciscan Complex rocks have been unconformably overlain by Tertiary age continental and marine sedimentary and volcanic rocks. These Tertiary age rocks have been locally overlain by younger Quaternary alluvial and colluvial deposits.

2.2 LOCAL GEOLOGY

The site and vicinity have been mapped by Graymer (2000) and Harding Lawson Associates (1982). The geologic maps prepared by these authors generally agree that the site is underlain by Late Cretaceous sedimentary rocks. Graymer described the site area as being underlain by "unnamed sedimentary rocks of the Great Valley Complex" that are characterized as "massive to distinctly bedded, biotite-bearing, brown-weathering, coarse- to fine-grained greywacke and lithic wacke, siltstone, and mudstone."

Landslide mapping performed by Nilsen (1975) indicates that there are no mapped landslides on the site or in the immediate vicinity. Documents supplied by LBNL (plans by LBNL entitled "North Gate Slide Repair, Hillside Stabilization, As-built Plan and

Section," dated March 12, 1975) indicate that there was a landslide along Cyclotron Road at the north end of the project site. The landslide was approximately 60-feet long, 100-feet wide and 12-feet deep. A slide repair was constructed in 1975 and consisted of removal of the slide debris and replacement with compacted engineered fill. The fill was keyed, benched into the underlying bedrock, and a subdrain was installed in the keyway. During this investigation, we found evidence of a dormant landslide within the building envelope that will be discussed below.

2.3 FAULTS AND SEISMICITY

The site, as well as the entire Northern California Coastal Region, is located within a seismically active portion of the state dominated by the presence of the San Andreas fault system, which forms the boundary between two tectonic plates of the earth's crust. At this boundary, the Pacific Plate (west of the fault) is moving north relative to the North American Plate (east of the fault). In the San Francisco Bay Area, this movement is distributed across a complex system of strike-slip, right-lateral, parallel, and sub-parallel faults that include the San Andreas, Healdsburg-Rodgers Creek, and Hayward among others.

The site is located within an Earthquake Fault Zone as defined by the California Geologic Survey (CGS, formerly California Division of Mines and Geology) in accordance with the Alquist–Priolo Earthquake Fault Zone Act of 1972. The Richmond (CGS, 1982), Oakland East (CGS, 1982) and Oakland West (CGS, 1982) quadrangles indicate the Hayward fault is located less than 1 kilometer to the west of the planned CRT site. Moderate to major earthquakes generated on the Hayward fault can be expected to cause strong ground shaking at the site. In addition, strong ground shaking can be expected from moderate to major earthquakes generated on other faults in the region such as the Concord-Green Valley fault (located 22 kilometers east of the site), the Calaveras fault (located 24 kilometers east of the site), the San Andreas fault (located 30 kilometers west of the site), and the Healdsburg-Rodgers Creek fault (located 36 kilometers north of the site). A number of large earthquakes have occurred within this region in the historic past.

Some of the significant nearby events include the 1989 Loma Prieta earthquake (M6.9), the 1906 San Francisco earthquake (M8+), the 1868 Hayward fault earthquake (M7), the 1838 San Francisco earthquake (M7+). Future seismic events in this region can be expected to produce strong seismic ground shaking at this site. The intensity of future shaking will depend on the distance from the site to the earthquake focus, magnitude of the earthquake, and the response of the underlying soil and bedrock.

3.0 PREVIOUS STUDIES AND AERIAL PHOTO REVIEW

Several fault investigations have been conducted by consultants in the general site vicinity within the Earthquake Fault Zone along the Hayward fault. The CGS (2003) has compiled those investigations in Northern California that were performed between 1974 and 2000 onto a six CD reference set, which was reviewed for this study. We reviewed the complete reports on 13 sites in the immediate vicinity from the CD sets, as well as recent work by Fugro West Inc. (2002) for the Building 50X site which is located directly north of the planned CRT site. The locations of study sites and the reports reviewed are presented on Plate 7, Previous Fault Investigations. Of the 13 CGS (2003) reports reviewed, 5 of the reports identified fault traces by subsurface exploration. For the purposes of discussion in this report, we will refer to the study sites by the site number presented on the CGS (2003) discs. Full reference for these studies can be found in the References Section (7.0) of this report.

CGS Site 2602: The Preliminary Study utilized published information including maps and aerial photos to conclude that there is no active trace of the Hayward fault crossing the site.

CGS Site 2815: The Preliminary Study incorporated review of published and unpublished geologic information as well as a site visit to conclude that active traces of the Hayward fault do not cross the site.

CGS Site 2601: An active trace of the Hayward fault (presumed to be the west trace) was located in four trenches excavated at the site. The risk associated with ground rupture and strong seismic shaking at the site was described in the report as moderate to high.

CGS Site 2529: Eight reports were located for this site (UC Berkeley campus) for various projects. Extensive subsurface information was collected in the form of test borings, trenches, and seismic refraction surveys. The general findings indicated that the main trace of the Hayward fault is approximately located as shown on the published maps and previous studies. Additional reports explored the Lauderback fault trace and concluded through exposures observed during trenching and radiometric dating that this fault is not active.

CGS Site 2646: Subsurface exploration consisted of 22 borings and 7 seismic refraction profiles to address fault hazard for the existing UC Berkeley campus buildings. The active main trace was located near Memorial Stadium and Bowles Hall. No evidence of faulting noted east of the active trace.

CGS Site 2211: Subsurface exploration (trenching and/or drilling) revealed no evidence of faulting on the site.

CGS Site 2530: Reports prepared for this site located the main trace of the Hayward fault along the northeast side of the project area at the approximate location shown on the CGS fault maps. The studies indicated that the fault trace crosses a sports field and that the nearest building is located approximately 60 feet to the southwest of the fault trace.

CGS site 0507: Subsurface exploration (trenching and/or drilling) revealed no evidence of faulting on the site.

CGS Site 0166: Subsurface exploration (trenching and/or drilling) revealed no evidence of faulting on the site.

CGS Site 1992: Subsurface exploration consisted of 6 borings and 2 trenches in which the main trace of the Hayward fault was located. The recorded trend of the fault at this location was N34°W dipping 80°W. A 40-foot-wide setback zone was recommended for the building addition.

CGS Site 0816: Surface mapping and review of published information indicated no evidence of faulting on the site.

CGS Site 2974: This site is part of a large re-construction area associated with the East Bay Hills fire of 1991. Subsurface exploration consisted of 29 borings and seismic refraction surveys. A zone approximately 40-feet wide was interpreted from seismic refraction data and field mapping to represent the main trace of the Hayward fault. Setbacks 50-feet wide were established on either side of the 40-foot fault trace zone creating a 140-foot-wide zone for non-occupied construction area.

CGS Site 0013: Surface mapping and review of published information indicated no evidence of faulting on the site.

Fugro 2002: Subsurface exploration consisted of excavating three trenches and revealed no evidence of faulting on the site.

We reviewed stereoscopic aerial photographs of the project area to observe tonal lineaments related to faulting. The photographs reviewed for this project were flown in 1947, 1957 1968, 1975, and 1988, and were provided to us by LBNL. Development in the site vicinity and vegetation growth inhibits visibility of surface features associated with faulting in the immediate site vicinity. Lineaments interpreted to be related to active faults are visible west of the site in some of the earlier photographs.

The photographs indicate that there is a well-defined topographic lineament at the base of the slope below the project area. This feature coincides with the documented fault traces of the Hayward fault.

4.0 SUBSURFACE EXPLORATION

4.1 FIELD EXPLORATION

Our field exploration was performed on April 17-19, 2006, and consisted of excavating and logging of two fault trenches, KT-1 and KT-2, at the approximate locations shown on Plate 2. The trenches were excavated using a track-mounted excavator equipped with a 30-inch-wide bucket. The trench was excavated to depths up to 12 feet below existing ground surface and was shored for safety. Due to localized, loose, wet upper soils, the upper portion of the trench was benched laterally on each side approximately 2 to 3 feet and to depths of 2 to 3 feet to prevent these soils from falling into the trench. The resultant excavation and upper bench were approximately 9-feet-wide. A 30-inch-wide trench approximately 7- to 10-feet-deep below the bench elevation was then excavated down the center of the excavation to reach the appropriate depths.

Trench KT-1 extended from the southeast corner of the proposed building site, west for 163 feet, along a trend of approximately N50-63°E. Trench KT-2 was excavated from the west edge of the planned building area toward Cyclotron Road along a trend of approximately N85-90°E. The trenches were oriented roughly perpendicular to the general mapped trend of the Hayward fault in the vicinity of the investigation for the possible existence of the main trace and any secondary traces or splays extending from this main trace. The excavations were logged by our Professional Geologists and Staff Geologist on a full-time basis under the supervision of our Certified Engineering Geologist.

Materials encountered in the trench were visually classified in the field and a log was recorded. The log of trench KT-1, describing the characteristics of the materials encountered, is presented on Plates 3A and 3B, and trench KT-2 is presented on Plate 4. Visual classifications were made in accordance with the Unified Soils Classification

System (USCS) presented on the Trench Log Legend, Plate 5, and Rock Description Criteria, Plate 6.

Upon completion of the field logging, the trenches were compacted and tested to 90 percent relative compaction in compliance with ASTM D-1557. Test results will be retained in our project files and can be reviewed upon request.

In addition, our Professional Geologist performed geologic/geomorphic mapping of the site and vicinity in April of 2006. The purpose of the geologic mapping was to identify surficial geologic and geomorphic conditions including existing and potentially adverse geologic conditions that could affect the project. The main focus of the geologic reconnaissance was to identify and assess geomorphic features consistent with active faulting and previous surface rupture. The results of the geologic reconnaissance are summarized on the Site Plan and Geologic Map, Plate 2.

4.2 SUBSURFACE CONDITIONS

Exposures within the trenches consisted of fill and colluvial deposits overlying residual soil, and ultimately, bedrock. Dormant landslide deposits were encountered in the lower section of KT-1 and throughout KT-2. The deposits directly overlie the bedrock, and are themselves overlain by younger colluvium.

4.2.1 Trench KT-1

At the east end of trench KT-1, fill (Unit 1) extends along the surface for approximately 47 feet. The fill is described as gravelly, sandy clay that is wet and medium stiff, and is 2- to 3-feet-thick. Colluvium (Unit 2) underlies the fill and comprises the surface soil unit down-slope of the fill. This deposit consists of sandy silt with gravel and gravelly silt with sand that is moist to wet and stiff to very stiff. This layer is approximately 2- to 3-feet thick with a localized area that is approximately 8 feet thick at station 130 in the infilled head scarp region of a dormant landslide. The colluvium is locally underlain by residual soil (Unit 3) consisting of gravelly silt with sand. The residual soil is wet, stiff to very stiff, and ranges from less than 1 foot to approximately 4.5 feet in thickness. Down slope of station 103, the colluvium is underlain by dormant landslide debris, classified as gravelly silt with sand that is wet and stiff to very stiff.

The residual soil and dormant landslide deposits are underlain by sedimentary bedrock (Unit 4 and Unit 5) of the Great Valley Sequence. The contact between the landslide deposits and bedrock is defined by a continuous, polished (clay seam) slip surface, while the residual soil/bedrock contact is highly gradational. Unit 4 consists of siltstone and Unit 5 of sandstone, both of which are moderately weathered, weak, and intensely fractured and locally closely fractured and crushed. The siltstone laterally grades into sandstone in several locations. The Great Valley Sequence bedrock was encountered to the maximum depth explored.

The bedrock units are locally brecciated in broad zones and also contain several more concise, clay-lined shears. In general, the shears are semicontinuous with no kinematic evidence suggesting recent activity. At station 40, two of these shears extend from the bedrock into the residual soil. The contact between the two units is not visibly offset, and as indicated above, no kinematic evidence for recent movement was observed along the shears. Hence these features are representative of old bedrock fractures or shears that can still be observed in the overlying residual soil unit, which is derived from highly weathered bedrock and is not considered to be related to active faulting along the Hayward fault. In addition, the shears strike N 30° E, and dip 22° to the southeast. Bedding within the bedrock units are consistent throughout the trench, striking between N 56° to 70° E and dipping 22° to 42° to the northwest.

As previously discussed, dormant landslide debris was encountered at station 130. The landslide slip surface extends from this point to the end of the trench. The residual soil (Unit 3) is absent down slope of station 103, suggesting it was incorporated into the debris and displaced down slope during the landslide event. The thickened colluvial soil at station 130 is consistent with infill of a headscarp or graben, post-landslide event.

Static groundwater level was not encountered in Trench KT-1. Minor seepage was observed in the landslide plane area and accumulated in the lower elevations of the trench.

4.2.2 Trench KT-2

The subsurface conditions in Trench KT-2 are comparable to those encountered down slope of station 103 in Trench KT-2. The colluvium (Unit 2) ranges in thickness between 4 and 9 feet. These deposits are underlain by dormant landslide debris (Unit 6) 0.5 to 2.5 feet thick. As in Trench KT-1, the landslide debris directly overlies Great Valley Sequence bedrock along a polished clay slip surface throughout the majority of the trench. Residual soil (Unit 3) underlies the slip surface at the west end of the trench. Bedding orientation of the bedrock in Trench KT-2 is consistent with KT-1, striking at N 60° E and dipping 28° to the northwest.

Static groundwater level was not encountered in Trench KT-2. Minor seepage was observed in the landslide plane area and accumulated in the lower elevations of the trench.

5.0 CONCLUSIONS

In general, the shears and shear zones identified within Trenches KT-1 are interpreted to represent features associated with regional tectonic deformation as opposed to surface rupture along the Hayward fault or an associated fault splay. As previously discussed, clay lined shears within the bedrock (Units 4, 5) visibly extend into the residual soil (Unit 3) which overlies the bedrock. The contact between Units 3 and 4 is very highly gradational, and as Unit 3 represents a completely weathered surface of the bedrock it overlies, preservation of structure (including discontinuities and shears) is not infeasible. The orientations of the features are nearly perpendicular to the trend of Hayward fault in the vicinity. As such, the clay lined shears likely represent relic structural features from the underlying bedrock mass, as opposed to active fault surface rupture. This explains the lack of contact offset or kinematic evidence along the shears.

The relative consistency of the northwest dipping siltstone and sandstone beds correlative between Trenches KT-1 and KT-2 and visible on either margin of the shears/shear zones, coupled with the lack of geomorphic features on trend with the shears/shear zones exposed in the trenches further precludes previous fault surface rupture at the site. The consistency of bedding orientation and lack of disaggregation implies the landslide event which occurred at the site did not extend further into the bedrock than the depth of the slip surface identified. Thus the shears and shear zones within the bedrock are unrelated to said landslide event. In addition, no concise shears or shear zones were identified in Trench KT-2.

Chemical or radiocarbon dating of the soils exposed within the trenches was not performed. Pedological development within colluvial soils is continually disrupted by the soil mixing inherent with surficial down slope creep. As such, pedological age analysis would be highly approximate at best. It is assumed the colluvial soils and landslide debris are likely Holocene to latest Pleistocene in age (<approximately 20,000 years old). The landslide event which occurred on site would act to remove/disrupt the soil record at the site, potentially removing evidence of surface rupture which occurred pre-landslide. However no shears or other evidence of faulting was identified beneath the landslide slip surface in Trench KT-1 or KT-2.

Based on the results of our investigation and analysis, we conclude that there is no evidence of active faulting or surface rupture at the planned CRT site. The nearest known active trace of the Hayward fault is located approximately 300 feet west of the site. As such, no fault-related building setbacks are required for this site.

6.0 LIMITATIONS

The scope of services was limited to the excavation of two (2) trenches, field mapping and review of previous fault studies in the area. It should be recognized that definition and evaluation of subsurface conditions are difficult. Judgments leading to conclusions and recommendations are generally made with incomplete knowledge of the subsurface conditions present due to the limitations of data from field studies. The conclusions of this assessment are based on Trenches KT-1 and KT-2, excavated to a maximum depth of approximately 12 feet below the existing ground surface.

Kleinfelder offers various levels of investigative and engineering services to suit the varying needs of different clients. Although risk can never be eliminated, more detailed and extensive studies yield more information, which may help understand and manage the level of risk. Since detailed study and analysis involves greater expense, our clients participate in determining levels of service, which provide information for their purposes at acceptable levels of risk. The client and key members of the design team should discuss the issues covered in this report with Kleinfelder, so that the issues are understood and applied in a manner consistent with the owner's budget, tolerance of risk and expectations for future performance and maintenance.

Recommendations contained in this report are based on our field observations and subsurface explorations. It is possible that soil, rock or groundwater conditions could vary between or beyond the points explored. If soil, rock or groundwater conditions are encountered during construction that differ from those described herein, the client is responsible for ensuring that Kleinfelder is notified immediately so that we may reevaluate the recommendations of this report. If the scope of the proposed construction, including the locations of the foundations, changes from that described in this report, the conclusions and recommendations contained in this report are not considered valid unless the changes are reviewed, and the conclusions of this report are modified or approved in writing, by Kleinfelder.

As the geological engineering firm that performed the geologic evaluation for this project, Kleinfelder should be retained to confirm that the recommendations of this report are properly incorporated in the design of this project, and properly implemented during construction. This may avoid misinterpretation of the information by other parties and will allow us to review and modify our recommendations if variations in the soil conditions are encountered.

Kleinfelder cannot be responsible for interpretation by others of this report or the conditions encountered in the field.

The scope of services for this subsurface exploration and fault investigation report did not include environmental assessments or evaluations regarding the presence or absence of wetlands or hazardous substances in the soil, surface water, or groundwater at this site. Kleinfelder cannot be responsible for interpretation by others of this report or the conditions encountered in the field.

7.0 REFERENCES

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Aerial Photographs

Date	Flight Line	Scale
3-24-47	AV11-03-11, 12	1:24,000
5-3-57	AV 253-09-22, 23	1:12,000
7-2-68	AV-858-01-20, 21	1:12,000
5-6-75	AV-1193-08-15, 16	1:12,000
8-3-88	AV 3368-9-21, 22	1:12,000

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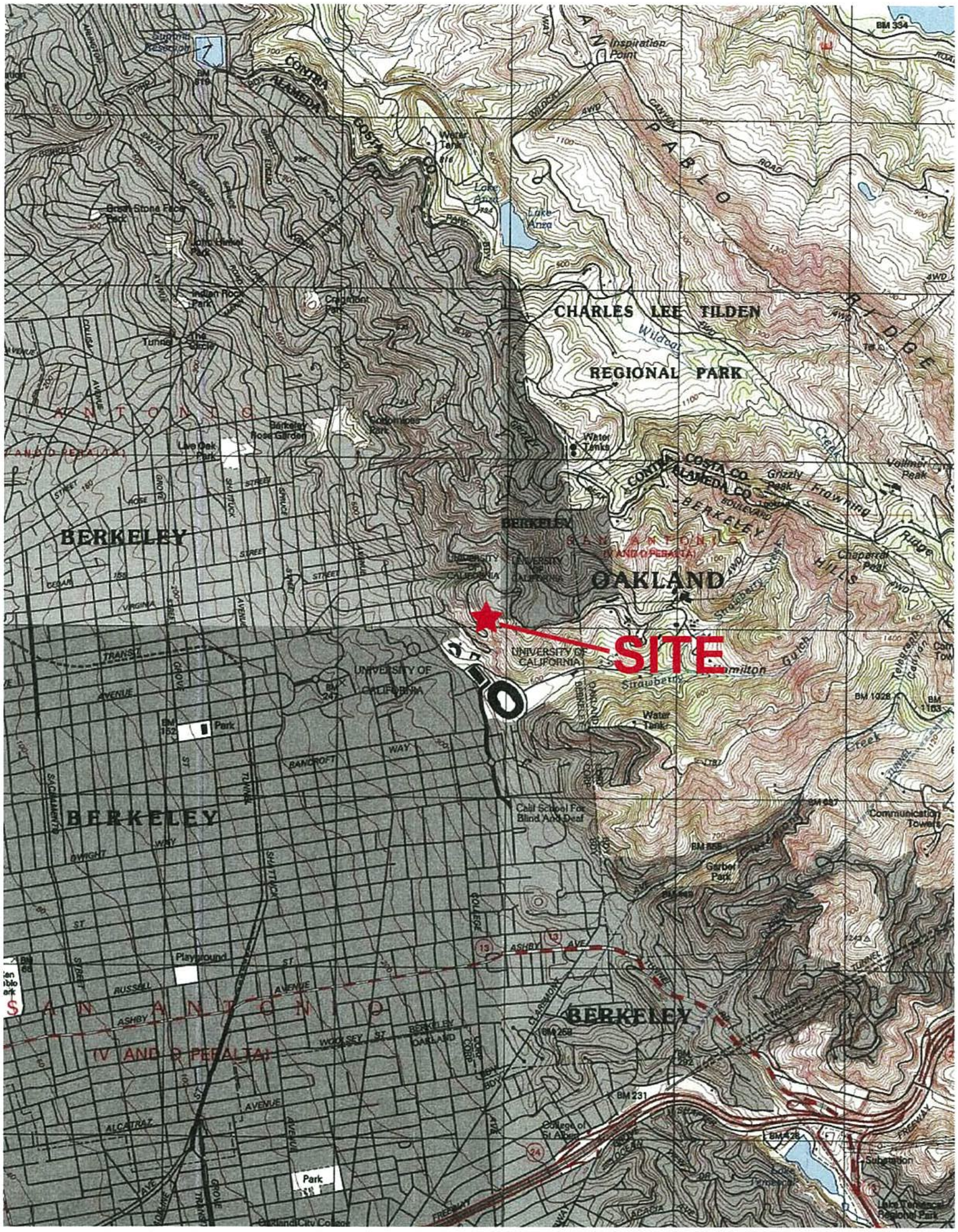
PLATES



3000 1500 0 3000

APPROXIMATE SCALE (feet)

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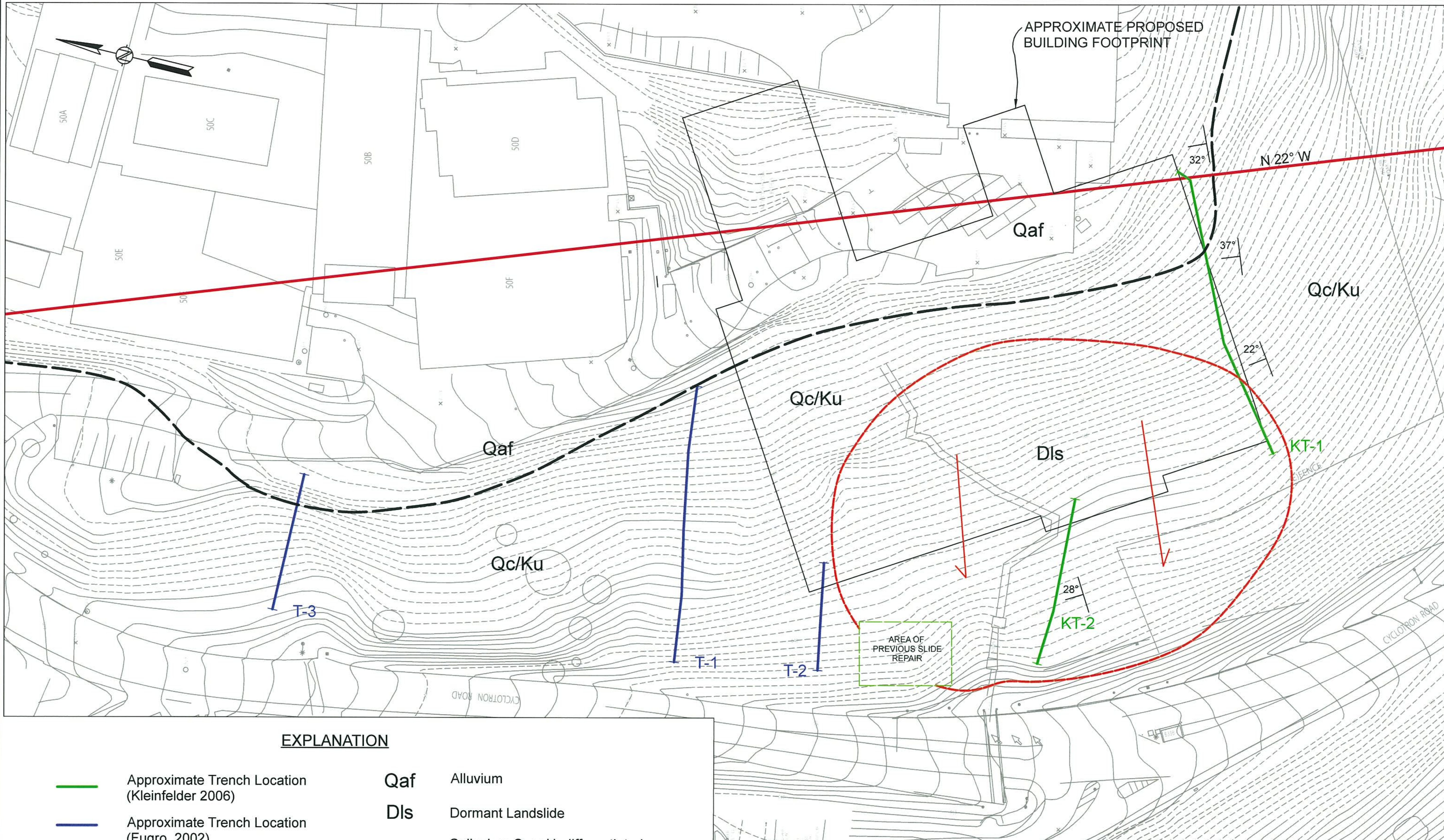
PROJECT NO.	67929
DRAWN	MAY 2009
DRAWN BY	JR
CHECKED BY	WM
FILE NAME	Site Location.ai

SITE LOCATION

FAULT INVESTIGATION: CRT BUILDING
LAWRENCE BERKELEY NATIONAL LABORATORY
BERKELEY, CALIFORNIA

PLATE

1



EXPLANATION

Symbol	Description
Green line	Approximate Trench Location (Kleinfelder 2006)
Blue line	Approximate Trench Location (Fugro 2002)
Red line	Eastern Boundary of the Alquist Priolo Earthquake Fault Zone
Qaf	Alluvium
Dls	Dormant Landslide
Qc/Ku	Colluvium Over Undifferentiated Great Valley Bedrock
28°	Bedding Orientation Exposed in Trench Excavation

50 25 0 50
APPROXIMATE SCALE (feet)

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PROJECT NO.	67929
DRAWN	MAY 2009
DRAWN BY	JCR
CHECKED BY	WVM
FILE NAME	Site_Plan_and_Geologic_Map.ai

SITE PLAN AND GEOLOGIC MAP

FAULT INVESTIGATION: CRT BUILDING
LAWRENCE BERKELEY NATIONAL LABORATORY
BERKELEY, CALIFORNIA

PLATE
2

UNIT DESCRIPTIONS

① GRAVELLY SANDY CLAY (CL) - mottled olive-brown dark olive-brown (5 Y 3/2 to 2.5 Y 3/2) very dark grayish-brown, dark yellow-brown, medium gray, wet, angular gravels to 2" diameter, medium stiff. P.P.=1 tsf, abundant roots (fill)

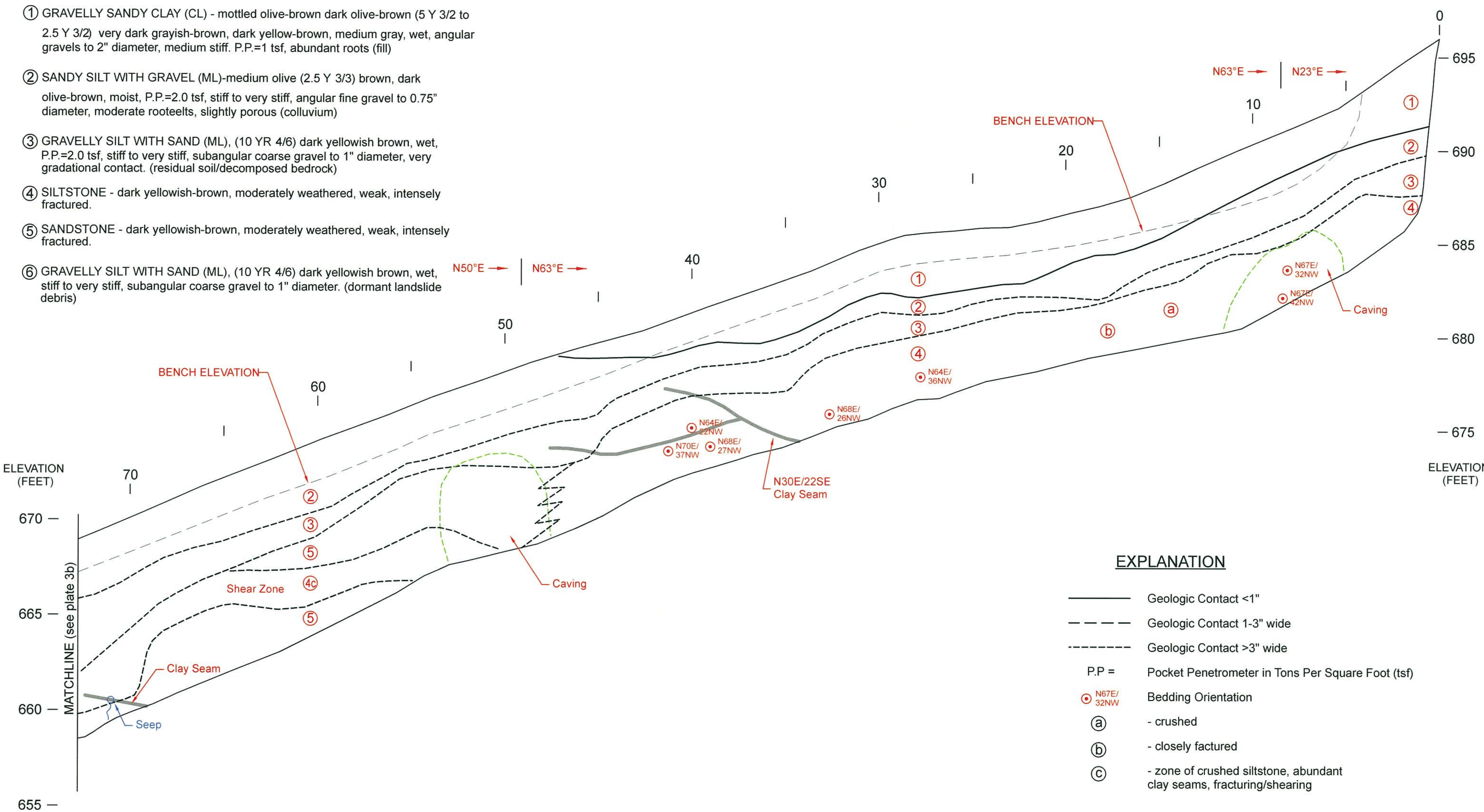
② SANDY SILT WITH GRAVEL (ML)-medium olive (2.5 Y 3/3) brown, dark olive-brown, moist, P.P.=2.0 tsf, stiff to very stiff, angular fine gravel to 0.75" diameter, moderate rooteelts, slightly porous (colluvium)

③ GRAVELLY SILT WITH SAND (ML), (10 YR 4/6) dark yellowish brown, wet, P.P.=2.0 tsf, stiff to very stiff, subangular coarse gravel to 1" diameter, very gradational contact. (residual soil/decomposed bedrock)

④ SILTSTONE - dark yellowish-brown, moderately weathered, weak, intensely fractured.

⑤ SANDSTONE - dark yellowish-brown, moderately weathered, weak, intensely fractured.

⑥ GRAVELLY SILT WITH SAND (ML), (10 YR 4/6) dark yellowish brown, wet, stiff to very stiff, subangular coarse gravel to 1" diameter. (dormant landslide debris)



EXPLANATION

———	Geologic Contact <1"
— — —	Geologic Contact 1-3" wide
- - - - -	Geologic Contact >3" wide
P.P =	Pocket Penetrometer in Tons Per Square Foot (tsf)
⊙ N67E/ 32NW	Bedding Orientation
ⓐ	- crushed
ⓑ	- closely factured
ⓒ	- zone of crushed siltstone, abundant clay seams, fracturing/shearing

5 2.5 0 5
APPROXIMATE SCALE (feet)

ILLUSTRATOR FILE: U:\GEOTECH_PROJECTS\Illustrator_Templates

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PROJECT NO. 67929	**LOG OF FAULT TRENCH KT-1**	PLATE
DRAWN MAY 2009		**3A**
DRAWN BY JR	FAULT INVESTIGATION: CRT BUILDING LAWRENCE BERKELEY NATIONAL LABORATORY BERKELEY, CALIFORNIA	
CHECKED BY WM		
FILE NAME Log_KT-1A.ai		

UNIT DESCRIPTIONS

① GRAVELLY SANDY CLAY (CL) - mottled olive-brown dark olive-brown (5 Y 3/2 to 2.5 Y 3/2) very dark grayish-brown, dark yellow-brown, medium gray, wet, angular gravels to 2" diameter, medium stiff. P.P.=1 tsf, abundant roots (fill)

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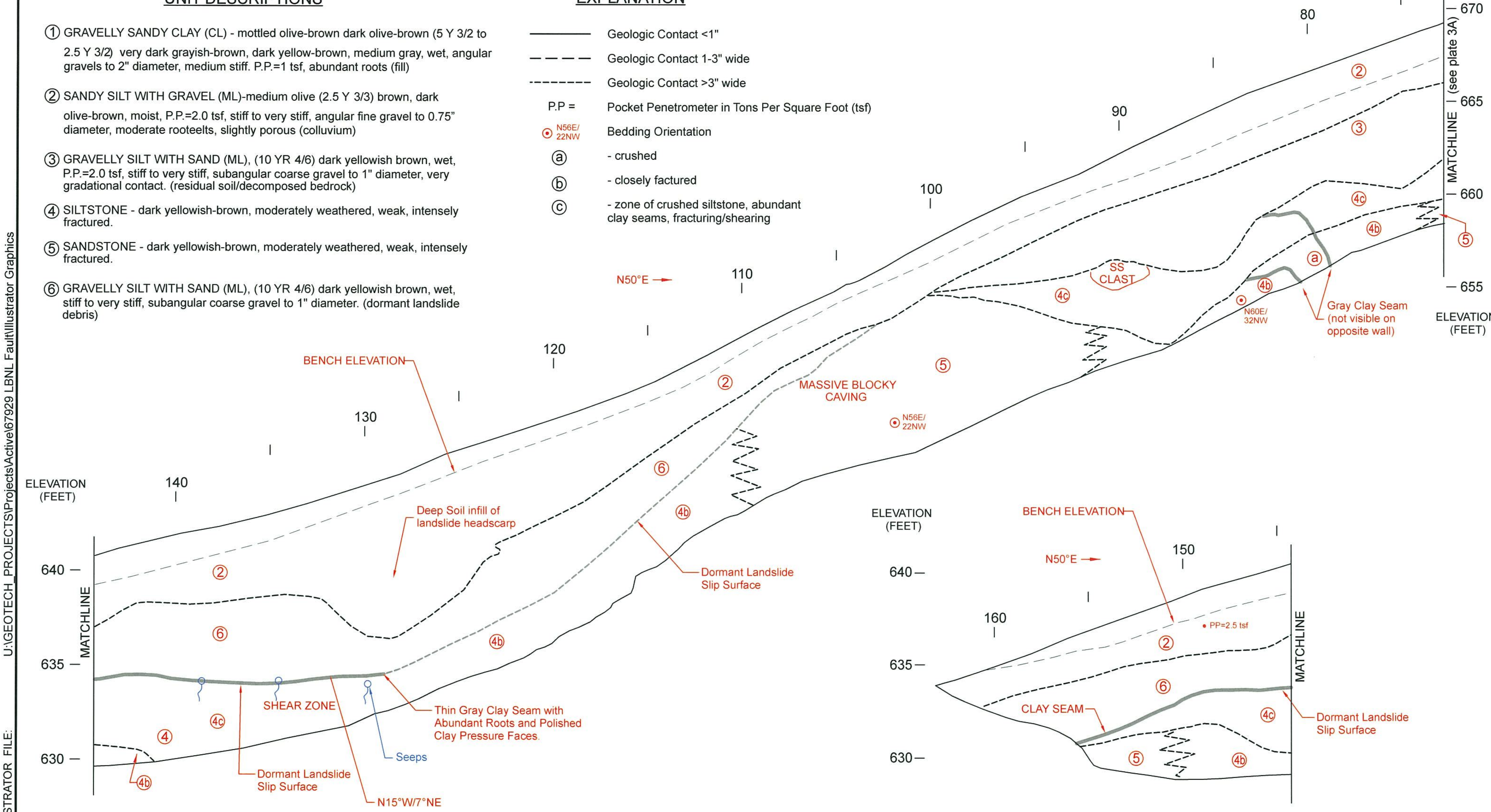
⑥ GRAVELLY SILT WITH SAND (ML), (10 YR 4/6) dark yellowish brown, wet, stiff to very stiff, subangular coarse gravel to 1" diameter. (dormant landslide debris)

EXPLANATION

———	Geologic Contact <1"
— — —	Geologic Contact 1-3" wide
- - - - -	Geologic Contact >3" wide
P.P =	Pocket Penetrometer in Tons Per Square Foot (tsf)
⊙ N56E/22NW	Bedding Orientation
ⓐ	- crushed
ⓑ	- closely factured
ⓒ	- zone of crushed siltstone, abundant clay seams, fracturing/shearing



5 2.5 0 5
APPROXIMATE SCALE (feet)

ILLUSTRATOR FILE: U:\GEOTECH_PROJECTS\Projects\Active\67929 LBNL Fault\Illustrator Graphics

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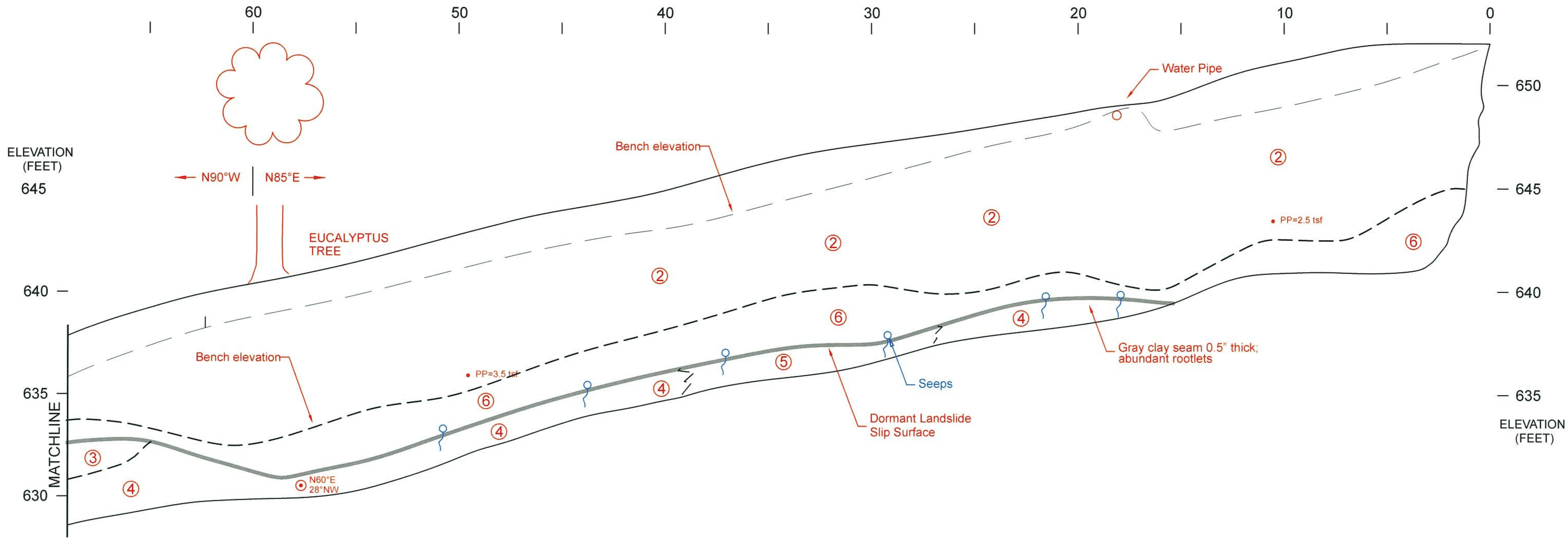
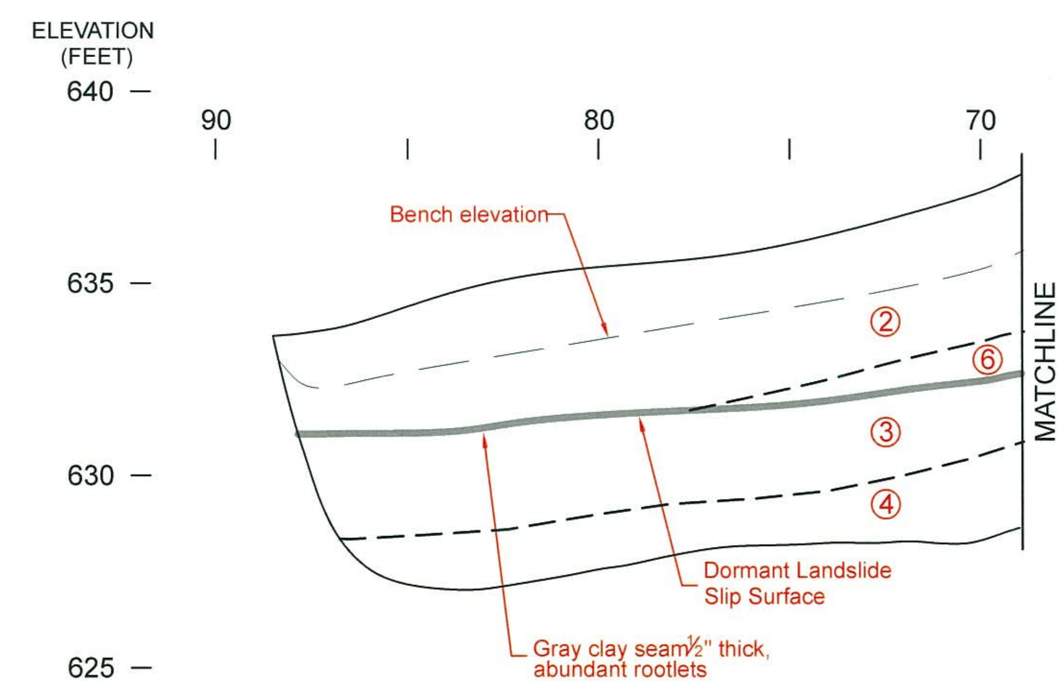
PROJECT NO.	67929
DRAWN	MAY 2009
DRAWN BY	JR
CHECKED BY	WM
FILE NAME	Log_KT-1b.ai

LOG OF FAULT TRENCH KT-1

FAULT INVESTIGATION: CRT BUILDING
LAWRENCE BERKELEY NATIONAL LABORATORY
BERKELEY, CALIFORNIA

PLATE
3B





UNIT DESCRIPTIONS

① GRAVELLY SANDY CLAY (CL) - mottled olive-brown dark olive-brown (5 Y 3/2 to 2.5 Y 3/2) very dark grayish-brown, dark yellow-brown, medium gray, wet, angular gravels to 2" diameter, medium stiff. P.P.=1 tsf, abundant roots (fill)

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⑤ SANDSTONE - dark yellowish-brown, moderately weathered, weak, intensely fractured.

⑥ GRAVELLY SILT WITH SAND (ML), (10 YR 4/6) dark yellowish brown, wet, stiff to very stiff, subangular coarse gravel to 1" diameter. (dormant landslide debris)

EXPLANATION

———	Geologic Contact <1"
— — —	Geologic Contact 1-3" wide
- - - - -	Geologic Contact >3" wide
P.P =	Pocket Penetrometer in Tons Per Square Foot (tsf)
⊙ N60°E 28°NW	Bedding Orientation
ⓐ	- crushed
ⓑ	- closely factured
ⓒ	- zone of crushed siltstone, abundant clay seams, fracturing/shearing

5 2.5 0 5
APPROXIMATE SCALE (feet)

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LOG OF FAULT TRENCH KT-2

FAULT INVESTIGATION: CRT BUILDING
LAWRENCE BERKELEY NATIONAL LABORATORY
BERKELEY, CALIFORNIA

PLATE
4

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UNIFIED SOIL CLASSIFICATION SYSTEM

MAJOR DIVISIONS				DESCRIPTIVE NAMES
COARSE GRAINED SOILS 50% is greater than #200 sieve	**GRAVEL** % GRAVEL > % SAND	CLEAN GRAVEL WITH LITTLE OR NO FINES (<=5%)	**GW**	WELL GRADED GRAVEL, GRAVEL-SAND MIXTURES
			GP	POORLY GRADED GRAVEL, GRAVEL-SAND MIXTURES
		GRAVEL WITH > 12% FINES	**GM**	SILTY GRAVEL, POORLY GRADED GRAVEL-SAND-SILT MIXTURES
			GC	CLAYEY GRAVEL, POORLY GRADED GRAVEL-SAND-CLAY MIXTURES
	SAND % SAND > % GRAVEL	CLEAN SAND WITH LITTLE OR NO FINES (<=5%)	**SW**	WELL GRADED SAND, GRAVELLY SAND
			SP	POORLY GRADED SAND, GRAVELLY SAND
		SAND WITH > 12% FINES	**SM**	SILTY SAND, POORLY GRADED SAND-SILT MIXTURES
			SC	CLAYEY SAND, POORLY GRADED SAND-CLAY MIXTURES
FINE GRAINED SOILS 50% passes #200 sieve	**SILT AND CLAY** LIQUID LIMIT LESS THAN 50		**ML**	INORGANIC SILT AND VERY FINE SAND, ROCK FLOUR, SILTY OR CLAYEY FINE SAND, OR CLAYEY SILT WITH SLIGHT PLASTICITY
			CL	INORGANIC CLAY OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAY, SANDY CLAY, SILTY CLAY, LEAN CLAY
			OL	ORGANIC CLAY AND ORGANIC SILTY CLAY OF LOW PLASTICITY
	SILT AND CLAY LIQUID LIMIT GREATER THAN 50		**MH**	INORGANIC SILT, MICACEOUS OR DIATOMACEOUS FINE SANDY OR SILTY SOILS, ELASTIC SILT
			CH	INORGANIC CLAY OF HIGH PLASTICITY, FAT CLAY
			OH	ORGANIC CLAY OF MEDIUM TO HIGH PLASTICITY, ORGANIC SILT
HIGHLY ORGANIC SOILS			**Pt**	PEAT AND OTHER HIGHLY ORGANIC SOILS

FIELD SAMPLING

- CALIFORNIA SAMPLE 2.5" I.D.
- MODIFIED CALIFORNIA SAMPLE 2" I.D.
- DISTURBED, BAG OR BULK SAMPLE
- STANDARD PENETRATION TEST
- SHELBY TUBE SAMPLE
- 3.5" I.D. CONTINUOUS CORE SAMPLE
- UNRETAINED PORTION OF SAMPLE
- HAND SAMPLER
- WATER LEVEL OBSERVED IN TEST PIT (at given post-excavation time)
- WATER LEVEL OBSERVED IN TEST PIT (at time of excavation)

LABORATORY TESTS

LL	LIQUID LIMIT
PI	PLASTICITY INDEX
SA	SIEVE ANALYSIS
#200	PERCENT PASSING #200 SIEVE
RV	RESISTANCE VALUE
EI	EXPANSION INDEX
DS	DIRECT SHEAR
Tx/UU	TRIAXIAL SHEAR-UNCONSOLIDATED UNDRAINED
UC	UNCONFINED COMPRESSION
SG	SPECIFIC GRAVITY
PP	POCKET PENETROMETER SHEAR STRENGTH (tsf)

The lines separating strata on the logs represent approximate boundaries only. The actual transition may be gradual. No warranty is provided as to the continuity of soil strata between test pits. Logs represent the soil strata and groundwater observed at the test pit location on the date of drilling only.

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PROJECT NUMBER **67929** DATE **5/13/2009**

TRENCH LOG EXPLANATION

Fault Investigation: CRT Building
Lawrence Berkeley National Laboratory
Berkeley, California

PLATE **5**

WEATHERING

Fresh - No visible sign of rock material weathering; perhaps slight discoloration on major discontinuity surfaces. **Weathering Grade I.**

Slightly Weathered - Discoloration indicates weathering of rock material and discontinuity surfaces. All the rock material may be discolored by weathering and may be somewhat weaker externally than in its fresh condition. **Weathering Grade II.**

Moderately Weathered - Less than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a continuous framework or corestones. **Weathering Grade III.**

Highly Weathered - More than half of the rock material is decomposed and/or disintegrated to a soil. Fresh or discolored rock is present either as a discontinuous framework or as corestones. **Weathering Grade IV.**

Completely Weathered - All rock material is decomposed and/or disintegrated to a soil. The original mass structure is still largely intact. **Weathering Grade V.**

Residual Soil - All rock material is converted to a soil. The mass structure and material fabric are destroyed. There is a large change in volume, but the soil has not been significantly transported. **Weathering Grade VI.**

STRENGTH (OF INTACT ROCK PIECES

Grade	Description	Field Identification	Approx. UCS (Mpa)	Approx. UCS (psi)
R0	Extremely Weak Rock	Identified by thumbnail	0.25 - 1.0	50 - 150
R1	Very Weak Rock	Crumbles under firm blows with point of geological hammer	1.0 - 5.0	150 - 750
R2	Weak Rock	Can be peeled by a pocket knife, specimen can be fractured with single firm blow of geological hammer	5.0 - 25	750 - 3,500
R3	Moderately Strong Rock	Cannot be scraped or peeled with pocket knife, specimen can be fractured with single firm blow of geological hammer	25 - 50	3,500 - 7,500
R4	Strong Rock	Specimen requires more than one blow of geological hammer to fracture it	50 - 100	7,500 - 15,000
R5	Very Strong Rock	Specimen requires many blows of geological hammer to fracture it	100 - 250	15,000 - 35,000
R6	Extremely Strong Rock	Specimen can only be chipped with geological hammer	>250	>35,000

DISCONTINUITY SPACING

	English	Metric
1. Extremely close	<1.0 in.	(<20 mm)
2. Very close	1.0 - 2.5 in.	(20 - 60 mm)
3. Close	2.5 - 8.0 in.	(60 - 200 mm)
4. Moderately	8.0 in - 2.0 ft.	(200 - 600 mm)
5. Wide	2.0 - 6.5 ft.	(600 - 2,000 mm)
6. Very wide	6.5 - 20.0 ft.	(2 - 6 m)
7. Ext. wide	>20.0 ft.	(>6 m)

APERTURE WIDTH

Very tight	<1.0 mm
Tight	0.1 - 0.25 mm
Partly open	0.25 - 0.5 mm
Open	0.5 - 2.5 mm
Moderately wide	2.5 - 10 mm
Wide	10 mm - 1 cm
Very wide	1 - 10 cm
Extremely wide	10 - 100 cm
Cavernous	>1 m

ROCK QUALITY DESIGNATION

RQD%	Rock Quality
90 - 100	Excellent
75 - 90	Good
50 - 75	Fair
25 - 50	Poor
0 - 25	Very Poor

RQD = Sum of Intact Pieces >4 inches (100 mm) / Total Core Run Length

■ Hand-Driven Tube Sample

P.P. +4.5 Pocket Penetrometer (tons per square foot, tsf)

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PROJECT NUMBER 67929 DATE 5/13/2009

ROCK DESCRIPTION CRITERIA

Fault Investigation: CRT Building
Lawrence Berkeley National Laboratory
Berkeley, California

PLATE
6

EXPLANATION

0816 — PREVIOUS FAULT INVESTIGATIONS (on file with California Geological Survey, CGS CD 2003-01, number indicates CGS file number)

FAULT TRACES MAPPED BY CGS

BOUNDARIES OF ALQUIST-PRIOLO EARTHQUAKE FAULT ZONE

CGS (2003) SITES	FAULT	
	FOUND	NOT FOUND
2602		X
2815		X
2601	X	
2529	X	
2646	X	
2211		X
2530	X	
0507		X
0166		X
1992	X	
0816		X
2974	X	
0013		X

Base: CGS (1983, 1993)

3000 1500 0 3000
APPROXIMATE SCALE (feet)

ILLUSTRATOR FILE: U:\GEOTECH_PROJECTS\Illustrator_Templates

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PROJECT NO. 67929	**PREVIOUS FAULT INVESTIGATIONS**	PLATE	
DRAWN MAY 2009			
DRAWN BY JR		7	
CHECKED BY WM	FAULT INVESTIGATION: CRT BUILDING LAWRENCE BERKELEY NATIONAL LABORATORY BERKELEY, CALIFORNIA		
FILE NAME Log_KT-1A.ai			