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STUDY PLAN APPROVAL FORM

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STUDY PLAN

for

STUDY 8.3.1.17.4.12
TECTONIC MODELS AND SYNTHESIS

U.S. GEOLOGICAL SURVEY

PREFACE

This study plan summarizes and extends the discussion of Study 8.3.1.17.4.12 in the Site Characterization Plan (SCP). Sections 1, 4 and 5 are drawn from the SCP and from related Yucca Mountain Project documents; the sections show the study in the context of the site characterization program. Sections 2 and 3 discuss the rationale, objectives, methods, and procedures of the planned activities in generally greater detail than the SCP.

The principal author of the study plan is Kenneth F. Fox, Jr. Frances R. Singer prepared sections 4 and 5, and shared in writing section 1. The study plan was extensively revised by D. W. O'Leary and W. B. Hamilton.

ABSTRACT

Study 8.3.1.17.4.12 will synthesize geologic and geophysical data in order to identify the tectonic processes operating in the Yucca Mountain region during the Quaternary Period, the rates of those processes, and the resulting geologic features. Based on published as well as new information resulting from the site characterization program, data will be used to formulate and test tectonic models and to evaluate tectonic disruption sequences that may impact the future stability of the area of the potential high-level nuclear waste repository. These forward projections of the kinds and rates of Quaternary processes are essential in locating and designing facilities important to safety and for estimating the effects of future tectonism and (or) volcanism on waste isolation at Yucca Mountain.

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STUDY 8.3.1.17.4.12
TECTONIC MODELS AND SYNTHESIS

1. PURPOSE AND OBJECTIVES OF THE STUDY

This study is part of the Yucca Mountain Site Characterization Study Plan (SCP; U.S. Department of Energy, 1988) preclosure tectonics program (see fig. 4-1) which is designed to gather and synthesize information needed to evaluate the tectonic stability of the Yucca Mountain area and the suitability of the geologic setting at Yucca Mountain to maintain high-level radioactive waste in isolation from the accessible environment. Because geologic mapping is essentially a sampling and an interpretive procedure, no geologic analysis is ever complete and no synthesis is ever exhaustive. The result is commonly a number of ambiguous or alternative interpretations of data. These interpretations can make sense, or be resolved, if they are cast in rationale explanations called models. A data synthesis is a summary interpretation of all geological data; a tectonic model is a construct or simulation applied to the synthesis that explains the data in terms of origin, structural and dynamic interrelations, and evolving behavior or response to changing stresses. We will employ two kinds of tectonic models: conceptual models and kinematic models. Conceptual models are explanatory/predictive constructs expressed as narrative or diagrams that are chiefly qualitative and have generalized applicability at any chosen scale. They incorporate both synthesized data and results of other kinds of models. A kinematic model describes the geometry and history of motion of a set of bodies that constitute the model. In physics, a kinematic model usually incorporates rigid objects that move relative to one another. The model describes these motions in terms of relative motion vectors. In geology, a kinematic model may incorporate a deformable body. An example of this would be a strain analysis where an initial and final geometry are compared in order to determine the motion of material within the deformed body.

The purpose of this study is twofold: to maintain an ongoing, iterative synthesis of data relevant to tectonics (i.e., stress, strain, rock deformation, igneous activity, earthquake history) acquired from multiple sources (chiefly the site characterization program), and to evaluate and develop tectonic models designed to predict the effects of future or ongoing tectonism at and around Yucca Mountain. The applications are therefore suitable for both preclosure and postclosure assessments. Detailed objectives of this study are (1) to guide future data acquisition (2) to develop a model or range of models that establishes the causal relation between application of tectonic forces and formation of structures and other tectonic phenomena observed at Yucca Mountain and vicinity, (3) to link inferred rates of formation of those structures with regional rates of crustal strain, (4) to weigh tectonic disruption scenarios in light of viable tectonic models, (5) to evaluate the state of tectonic stability and perturbations to stability at Yucca Mountain, and (6) to support probabilistic seismic hazard analysis and regional hydrologic analysis. To these ends, the study is organized into three activities:

- 8.3.1.17.4.12.1: Evaluate tectonic processes and tectonic stability at the site
- 8.3.1.17.4.12.2: Evaluate tectonic models relevant to the geologic setting
- 8.3.1.17.4.12.3: Evaluate tectonic disruption sequences

Objectives specific to each activity within the study are discussed in sections 3.1 through 3.3. Because this study is an ongoing, iterative procedure that brings together the results of many, more limited and topical analyses, it does not provide detailed procedural steps, nor is it a data source or catalogue, nor an analytical review; it is a plan that provides guidelines and objectives in outline form.

1.1 Information to be obtained and how that information will be used

1.1.1 Nature of information

Tectonic processes known to have operated within the Yucca Mountain region during Quaternary time include volcanism, igneous intrusion, folding, seismicity, faulting, uplift and subsidence, and lateral strain (crustal dilations and compressions associated or not associated with the processes cited above). This study will characterize the tectonic processes that operated during the Quaternary, the rates of those processes, and the resulting geologic structures and features. This study also will provide syntheses of data bearing on tectonics of the Yucca Mountain area. Although the main goal is to characterize features formed or active during Quaternary time, a broader analysis of features formed in late Tertiary time will also be needed to discriminate dormant from still-active features. The syntheses will include maps showing the spatial distribution of tectonic features and their chronologic relationships, and analyses interpreting their development through time. This study also will appraise and develop tectonic models which explicitly set forth the relationships between tectonic processes, their inferred rates during Quaternary time, and observed structures and other features of tectonic origin.

1.1.2 Area to be considered or evaluated

Study 8.3.1.17.4.12 contemplates synthesis of geologic and geophysical information and development of tectonic models and disruption sequences for an area that encompasses the geologic setting of Yucca Mountain. The term "geologic setting", as used in the context of this study, includes all of the geologic elements (structural, stratigraphic, volcanic, geomorphic) that characterize, affect, or contribute to the makeup and evolution of Yucca Mountain. Such a setting therefore includes all of the neighboring ranges and bounding basins, the proximal fault zones that distinguish the structural pattern of Yucca Mountain and surrounding areas (typical of the Southern Basin and Range), and all of the adjacent volcanic fields. Although specific boundaries cannot be drawn, most of these features, or significant portions of them, occur within 100 km of Yucca Mountain. Moreover, because seismicity within this radius is relevant to future deformation and ground shaking (see SCP Figure 8.3.1.17-6) at the potential repository

site, the 100 km area is considered to be a proper part of this geologic setting and to serve as a guide in defining the general scope of several of the tectonic studies that contribute data to Study 8.3.1.17.4.12 (fig. 1-1). The 100 km radius in no way limits consideration of geologic features that may be relevant to some models, processes, or tectonic scenarios. The geologic extent of the area to be evaluated is regional in the sense that some relevant tectonic mechanisms, such as lower crustal stress fields or upper mantle differentiation processes, operate at scales of hundreds of km. While it is not feasible to expand field studies to these extents, appropriate literature will be reviewed as necessary.

1.1.3 Sources of information

Information required to formulate and test the tectonic models needed to predict scale and extent of future tectonic deformation and volcanism includes existing geologic and geophysical maps and literature, both published and unpublished, and new data to be gathered as part of the Yucca Mountain site characterization program.

Published data. The broad outlines and many details of the geologic and tectonic setting are known through the extensive publications of the U. S. Geological Survey, Nevada Bureau of Mines and Geology, and the California Division of Mines and Geology, and through University-sponsored research by numerous graduate students and professors. This body of information continues to grow as additional research is completed. Published data available prior to 1988 is summarized in Chapter 2 of the SCP. Additional unpublished data gathered by government and university scientists also will be considered and integrated as available.

Characterization Program. A large body of tectonic, geologic and geophysical data has been acquired from within the Yucca Mountain region by studies of differing levels of quality, detail, and obsolescence. The project plans to selectively upgrade, supplement and modernize this data base through data-gathering activities included within the characterization program (Fig. 1-2). These activities are described within the SCP (chiefly Post- and Preclosure Tectonics, Programs 8.3.1.8 and 8.3.1.17, and Site Geology, Program 8.3.1.4). These and other programs included within the SCP (fig. 2-3) supply data to Study 8.3.1.17.4.12.

1.1.4 Uses of information

Tectonic models developed in this study provide the deductive link between empirical data on the identity, sites and rates of Quaternary tectonic processes, and forward projection to estimate the effect of future tectonism on waste isolation at Yucca Mountain. The Quaternary rates of tectonic processes will be projected forward to estimate the probable rates of those processes during the life of the potential repository. The forward projections will be used to help design facilities important to safety. An important product of the proposed study will be an evaluation of the uncertainty among models. In particular, reliability of the data on which

the models are based will be assessed. This will be useful for both the scenarios and for probabilistic analyses.

1.2 Rationale and justification for the information to be obtained - why the information is needed

Federal regulations (chiefly 10CFR960, U.S. Department of Energy, 1984, and 10CFR60, U. S. Nuclear Regulatory Commission, 1986) require investigations of the geology and tectonics of potential repositories. These regulations, and draft NRC Staff Technical Position Papers that amplify and explain elements of the regulations, include stipulations that impact the scope of syntheses to be prepared by this study, and underscore the importance of tectonic models. Evaluation of tectonic models and synthesis of supporting data is a comprehensive process designed to support evaluations of site suitability and performance assessments on a flexible, iterative basis that accommodates accruing data and new analytical techniques. This study will contribute to iterative site suitability evaluations and performance assessments as well as provide information for issue resolution. Modeling results will provide support for ongoing seismic hazard and hydrologic investigations and igneous activity assessments. In the paragraphs that follow we discuss that part of the rationale for this study that flows from these regulations and position papers.

Information on tectonic processes is needed to aid in predicting or appraising the occurrence or magnitude of geologic phenomena that may pose hazards to the potential repository; this knowledge can provide input for the assessment of repository performance or the performance of natural barrier systems, and design requirements for engineered facilities and engineered barrier systems. Likewise, particular tectonic disruption sequences, based on data synthesis, may be used to evaluate the probability that the occurrence of a tectonic event, such as faulting, might compromise preclosure or postclosure repository performance.

Tectonic models are needed to point up inconsistencies and uncertainties in the chronology of structural evolution. For example, the determination of slip rates on the various mapped faults, as determined by dating of offset strata, will be checked for consistency with interpretive tectonic models that account for the style and rate of faulting throughout the Yucca Mountain region. The tectonic models will also aid in resolving alternative interpretations of data sets, or even in providing a reasonable interpretation where data are so sparse or ambiguous that no specific indications are forthcoming. Field data are often difficult to interpret; they are often highly variable, the sample distribution is far from ideal, and the representativeness of the data often involves a high degree of uncertainty. Such data can make sense if they are seen in a broader, regional, or historical context. Tectonic models can provide such an interpretive framework for otherwise ambiguous data. For example, stratigraphic discrepancies in a map area might be resolved in inferring a thrust fault. This model resolution, in turn, provides specific structural criteria that must be supported if the model is to be tenable. A return to the field with a specific structural test in mind can lead to discovery of critical data that can support

or invalidate the model. Therefore, data synthesis and model generation are mutually reconciling efforts: models provide criteria and field tests and resulting new data refine the models.

Information from this study also will be used to evaluate the effects of future tectonic activity on erosion at Yucca Mountain (Study 8.3.1.6.3.1.1), and finally, the human interference program will use results from the study to assist in evaluating the natural resource potential of the Yucca Mountain area (Activity 8.3.1.9.2.1.2) since tectonism is an important factor in the control and location of hydrothermal mineralization.

1.2.1 Importance and limitations of the Quaternary record

In accordance with 10CFR60.122, projections or rates of tectonic processes into the future are to be based on forward extrapolation of the measured rates at which these processes operated during Quaternary time. The Tectonics Programs (8.3.1.8 and 8.3.1.17) accordingly focus chiefly on the Quaternary record.

Although Quaternary deposits are abundant in the Yucca Mountain region, confidently dated horizons are sparse. The oldest Quaternary deposits generally recognizable are those assigned to a unit designated as alluvium of Quaternary-Tertiary age (QTa; Hoover, 1989), which is composed chiefly of shingled debris flows, and (in the Amargosa Desert) fluvial facies containing in their upper part a tephra dated at 2.1 ± 0.4 Ma (Hoover, 1989, p. 36-37). QTa is unconformably overlain by surficial deposits containing a tephra deposit correlated with the Bishop Ash (about 740,000 years old; Izett, 1982). The erosional top of QTa, which forms a useful datum within the Yucca Mountain region, is cut by faults, but no evidence of faulting or other tectonism during deposition of QTa has been recognized. It is difficult to recognize codepositional faulting in alluvial units because of cut and fill processes, nonconsolidation, etc.. Any faulting concurrent with QTa (that is prior to about 1 ma) thus cannot be distinguished from pre-Quaternary faulting. Faults that cut QTa but not the overlying strata are bracketed by about 740,000 yr and 2.1 Ma. Thus, although we would prefer to use the entire Quaternary Period as a basis for tectonic models and rate projections, the basis will likely be limited to that part of the Quaternary following deposition of QTa in those areas where QTa is preserved; elsewhere, local criteria will be used as constraints are available. Information on pre-Quaternary tectonic processes also must be considered where it supplies context useful in evaluating the Quaternary processes and rates. For example, seismic reflection profiling may be used to identify buried unconformities or faults indicative of early Quaternary or Tertiary tectonism. Other geophysical techniques, such as electrical resistivity or magnetic profiling may be used to trace buried faults, and radiometric dating techniques may be used to constrain Quaternary or late Tertiary burial or tilting events.

1.2.2 Required areal extent of tectonics investigations

Applicable regulations (10CFR60) call for analysis of favorable conditions within the geologic setting, and of potentially adverse conditions within the controlled area. "Favorable conditions" involve "the nature and rates of tectonic, hydrogeologic, geochemical, and geomorphic processes (or any of such processes) operating within the geologic setting during the Quaternary Period (which), when projected, would not affect or would favorably affect the ability of the geologic repository to isolate the waste" (10CFR60.122). The site assessment, a required component of the application for license, shall contain "analyses to determine the degree to which each of the favorable and potentially adverse conditions, if present, has been characterized, and the extent to which it contributed to or detracts from isolation" (10CFR60.21). In accordance with these requirements, the synthesis of tectonic information and the area to which the tectonic models developed by this study are to be applied encompasses not only the site but also the geologic setting, or Yucca Mountain region.

1.2.3 Required support of tectonic models used to predict conditions within the geologic setting

According to regulation 10CFR60.21(ii)(B), tectonic models will contribute to determination of "the degree to which each of the favorable and potentially adverse conditions, if present, has been characterized, and the extent to which it contributed to or detracts from isolation". The tectonic models are predictive models, in the terminology of these regulations; they will be used to aid in predicting future rates and locations of tectonic processes, such as volcanism and faulting, within the site area and the geologic setting. Further, "Analyses and models that will be used to predict future conditions and changes in the geologic setting shall be supported by using an appropriate combination of such methods as field tests, in situ tests, laboratory tests which are representative of field conditions, monitoring data, and natural analog studies" (10CFR60.21(ii)(F)). According to these regulations, the assessment included within the Safety Analysis Report must contain an explanation of measures used to support these predictive tectonic models.

To satisfy these requirements, tectonic models used to predict future conditions within the geologic setting will be supported through collection, compilation, and synthesis of data which bear on the validity of these models. Synthesis of data and development of tectonic models is the responsibility of this study. Collection of additional data is chiefly the responsibility of the data collection studies included within the Tectonics Programs (8.3.1.8 and 8.3.1.17) (figs. 2-1 and 2-2). This study will also contribute to planning of possible additional data collection efforts through recognition of additional alternative models and specification of the information required to validate those models.

Some tectonic models possibly applicable to Yucca Mountain and vicinity are based on interpretations of distant regions such as western Utah and southeastern California. The weight given to such models will depend on factors that include distance from Yucca Mountain and the extent to which the analogous area itself is understood, and the extent to which the distant

tectonic setting is directly analogous to that of Yucca Mountain. Any such evaluation of distant tectonic features will be based on existing data, however, without further field investigation and will be only a minor, but potentially important, part of this activity.

1.2.4 Elements of tectonic models

Elements of tectonic models include (SCP, pages 8.3.1.8-30 and 8.3.1.17-37):

Physical domain The space to which the model applies.

Driving forces/processes Forces and processes acting within the physical domain that produce the observed features of the model.

Boundary conditions Status of external forces, conditions, and processes at the boundary of the physical domain.

System geometry Arrangement of physical components of the model within the physical domain, including, for example, faults, blocks, volcanic vents, and convection cells.

System response/dynamics Behavioral aspects of the model relevant to waste isolation. Among these are included mechanisms and frequency of faulting, fault rupture sequences, extension rates, generation and rate of volcanism, variations of groundwater flow, and effects of elevating water table, as well as chemical properties along flow paths and the results of dynamic behavior, including distribution of faulting events, seismic potential, and volcanism.

1.2.5 Tectonic models hierarchies

We classify tectonic models in two ways: first, according to the size of the domain to which they apply; second, according to their application to repository performance.

Size of domain Tectonic models vary significantly according to the size of the domain to which the model applies. We distinguish four classes: (1) global, applying to the entire earth or a large part of it (e.g. plate-tectonic models), (2) provincial, applying to geologic provinces in their entirety, (e.g. Basin and Range Province), (3) Yucca Mountain region, applying to the geologic setting of Yucca Mountain, and (4) local, applying to the potential site area at Yucca Mountain. Although global and provincial models are not formally considered part of this study, features of these models are used, where appropriate, as boundary conditions of regional models that do apply.

Application to performance With respect to repository performance, models have been divided into two groups, or *tiers*. The higher tier includes models that explain geologic and tectonic features in terms of processes, but without specific consideration of repository performance. The lower tier includes models which, through further development of hypotheses and supporting data, predict repository performance on the assumption that a particular upper tier model is correct. See section 2.2.1 for additional discussion of this distinction.

1.2.6 Role of alternative models

Alternative models are models which vary in important details but which appear to explain some or all of the existing data pertaining to a domain equally well. Alternative models may vary significantly in their prediction of the capability of the geologic setting to isolate waste. An initial set of alternative tectonic models applicable to the region and to the area proximal to Yucca Mountain have been formally set forth in SCP Tables 8.3.1.8-7 and -8, and 8.3.1.17-7 and -8. We expect that some of these models will be rejected as characterization proceeds, that others will be found viable, and that new alternative models will be proposed. Evaluation of alternative models will proceed by well-documented analysis based on well-formulated criteria. A good model provides an explanation that affords forecasting and hindcasting as tests for its robustness. On this basis, a model can be accepted, or validated, on its ability to forecast (i.e., a predicted event occurs) or by its ability to hindcast (i.e., new or additional data of a given type and from a given place are found that support a postulated past event or condition of the model, or a simulation mimics a given data set). A model can be rejected if it conflicts with a known or a new data set, or if a simulation cannot mimic a given data set. A model is permissive if it presents no data conflicts either by inspection or by simulation, but is not tested by forecasting or hindcasting (i.e., a "critical experiment" cannot be devised for one reason or another).

1.2.7 Use of tectonic models in assessment of design and performance

Study 8.3.1.17.4.12 will use tectonic models (1) to ensure that assumptions, inferences, and conclusions concerning tectonic processes that are important to design and performance of the repository are consistent with the entire data base; and (2) to ensure that uncertainty in the data, assumptions, and inferences concerning rates and nature of those tectonic processes that are important to design or performance of the repository is adequately reflected in conclusions about those processes.

Tectonic models may be used to assess the location and recurrence characteristics of faulting during the preclosure and postclosure periods. Performance assessments will thus be based on tectonic models, in that (1) projections of deterministically and probabilistically determined rates of tectonic processes will be justified by evaluation and acceptance of relevant models, (2) the uncertainty associated with projected rates of tectonic processes will reflect all credible alternative models, (3) in some cases, bounding values of rates will be derived through direct

appeal to models, (4) alternative models will be used to identify anticipated and unanticipated processes and events, and (5) alternative models will be used to develop scenarios. This information could provide input to design of structures, systems, and components important to safety and waste isolation.

1.2.8 Use of tectonic models in recognition of Quaternary processes and events

The widespread alluvial deposition in the Yucca Mountain region during Quaternary time has hidden much of the record of tectonic events; either evidence of faulting was obliterated by successive episodes of cutting and filling, or has been covered by thick alluvium, or both. The older the record, the more obscure the tectonic phenomena in general. However, the fragmentary tectonic record that does exist can be filled in by appropriate use of alternative tectonic models. Likewise, tectonic features that are otherwise enigmatic, such as the many steep faults that transect Yucca Mountain and its alluvial flanks, can be rationalized by applying tectonic models; these faults could be modeled to extend through the seismogenic crust, or to merge into detachments at relatively shallow depths, or to have other configurations.

Interpretations based on tectonic models can be used, therefore, to qualify tectonic disruption scenarios, and to postulate Quaternary processes and events that, although not evidenced at the surface, can be tested and perhaps recognized in the context of those tectonic models. For example, a model that assumes the involvement of detachment faults can be used to explain late Quaternary activity among many sub-parallel normal faults, can support a disruption scenario involving distributed faulting, and can constrain the search for particular faulting styles in the subsurface.

1.2.9 Use of tectonic models in scenario selection

In order to comprehend a plausible range of processes and events that could impact the repository, DOE has chosen to develop a comprehensive list of disruptive scenarios (a given succession of processes and events constitutes a "scenario") and to calculate prospective releases based on these scenarios (SCP, section 8.3.5.13.2). Accordingly, appropriate alternative tectonic models must be available to ensure adequate evaluation of significant anticipated processes and events and unanticipated processes and events. Tectonic disruption sequences are the tectonic components of disruptive scenarios and will therefore be provided by this study to aid in establishing a range of most likely to least likely events. Evaluations will consist of (1) classification of the sequence of events as anticipated or unanticipated, and (2) consideration of the potential disruptive effect of the sequence of events on the engineered and geologic barrier system or on facilities important to safety. Evaluations are to be supported by explanatory notes, and citations of relevant data and interpretations. Evaluation of tectonic disruption sequences will occur in the context of "scenarios", and will be in terms of specific location, nature of geologic and environmental influences, and estimation of probability of recurrence. However,

consideration of the manner in which the disruption sequences could influence repository performance is delegated to applicable performance and assessment investigations.

2. RATIONALE FOR SELECTING THE STUDY

Study 8.3.1.17.4.12 is designed to synthesize information pertaining to tectonics, to identify tectonic processes, and to develop tectonic models using data collected by studies in both the Preclosure (8.3.1.17) and Postclosure (8.3.1.8) Tectonics Programs, data from the existing database, and data from other relevant studies within the site characterization program (Figs. 2-1 and 2-2). The path taken in transferring information from the existing database and from data collection studies to ultimate users is shown in fig. 2-3. Much of the data that will be synthesized and the results of the modeling efforts to be conducted in this study will be directed back into studies and activities in both the preclosure and postclosure tectonics investigations (identified as Tectonics Analysis and Assessment Investigations on Figure 2-3), which deal with collecting, analyzing, and assessing data bearing on the potentially disruptive effects of tectonic events and processes on the potential repository. Some of the study results may flow directly to users of these kinds of data who are involved in higher level findings, license applications, etc., as shown on Figure 2-3.

Another method of synthesizing data and developing tectonic models and tectonic disruption sequences would be to distribute responsibility for synthesis and model development to the various individual data collecting studies in the preclosure and postclosure tectonics programs. Specific reasons for assigning these activities to a separate study (i.e., 8.3.1.17.4.12), however, include: (1) reduction of unnecessary overlap, (2) encouragement of a synoptic view of data, (3) avoidance of data omissions, and (4) simplification of information flow.

The basis for selecting the types of tests that are planned for each of the three activities within this study are discussed below. The test plans themselves are discussed in section 3.

2.1 Activity 8.3.1.17.4.12.1: Evaluate tectonic processes and tectonic stability at the site

Evaluations will be based on synthesis of data pertaining to the tectonic processes of volcanism, igneous intrusion, folding, faulting, seismicity, uplift and subsidence, and lateral strain, and others that may be identified at the site (fig. 1-2). Syntheses will include maps and summary reports that incorporate geologic, tectonic and geophysical data supplemented by topical reports on specific processes or subprocesses.

Additional evaluation may be performed contingent on successful application of a boundary element modeling technique. The boundary element technique is fundamentally a mathematical analysis of the behavior of solid masses based on knowledge of material properties and on response to stress imposed on the masses at the physical boundaries.

The boundary element method applies to a region of fixed properties: a viscoelastic halfspace that represents the seismogenic crust, resting on an inviscid layer that represents the

ductile lower crust. The model assumes that the upper seismogenic zone of the crust, (~ 15 km) together with the lower (viscous) part, behaves in an elastic fashion at the time of an earthquake. Between earthquakes the lower crust relaxes by creep. Incomplete relaxation also occurs in the seismogenic zone such that its long term elastic modulus is substantially lower than that determined in the short term. This reduction of modulus is conveniently described by assigning to the seismogenic layer an "effective elastic thickness" lower than its true thickness. The elastic component of deformation is an important variable, whereas the viscous component in dealing with seismogenic fault displacement is ignored. This, however, is not meant to imply that there are no viscous properties in the crust.

The boundaries of any area of examination consist of faults having a fixed geometry and shear strength. Because the model is two-dimensional (i.e., deals with cross sections or planimetric areas) the geometry of the boundaries consist of line segments. A series of equations defines the boundary conditions in terms of form, displacement, and/or stress for each segment. The bounded body is divided into a grid of N elements; the deformation (strain, displacement) applied to each element, i, in the bounded body is a function of the stresses applied to each boundary element, j. The displacement and stresses are computed for every element. Alternatively, the form of the bounded body can be fixed and the stresses can be calculated for the boundary itself.

The physics of the bounded body is described by partial differential equations that define strain (particle displacement), and normal and shear stresses (s, t) related by Hooke's law of elastic deformation. Faults within the deformed body are modeled by a displacement discontinuity along and across which the displaced elements are specified by displacement (D) in xy space. If a sufficient number of constraints are imposed on a boundary, a unique solution to the differential equations and the boundary conditions exist.

The variable are:

D="displacement discontinuity" (displacement of element j in xy space).

A="boundary influence coefficient" for each stress affecting element i.

B="boundary influence coefficient" for each displacement affecting element i.

(A and B, the "influence coefficients" are functions of elastic properties that include Poisson's ratio and Young's modulus.)

If a D is applied to each of the j segments of a fault, then the shear and normal stresses at the midpoint of each element i are calculated:

$$\tau^i = \sum_{j=1}^{N} A_{xx}^{ij} D_x^j + \sum_{j=1}^{N} A_{xy}^{ij} D_y^j$$

$$\sigma_n^i = \sum_{j=1}^{N} A_{yx}^{ij} D_x^j + \sum_{j=1}^{N} A_{yy}^{ij} D_y^j \qquad i=1,N$$

Typically, τ and σ_n are specified for each fault and A is estimated, so the 2N simultaneous linear equations are computed for the unknowns D_x and D_y, the displacements and stresses for each element within the body can be computed:

$$u_\tau^i = \sum_{j=1}^{N} B_{xx}^{ij} D_x^j + \sum_{j=1}^{N} B_{xy}^{ij} D_y^j$$

$$u_\sigma^i = \sum_{j=1}^{N} B_{yx}^{ij} D_x^j + \sum_{j=1}^{N} B_{yy}^{ij} D_y^j \qquad i=1,N$$

The computer program (See Appendix) solves for the linear equations and sums the influences of every displacement discontinuity or influence coefficient that depend on position and elastic properties. The program input (boundary displacement values, stresses, elastic properties) are adjusted in order to make the resultant graphic model output fit the known geology of the modeled area in terms of fault displacement, bending, and topographic profile.

The model is sensitive to relative positions of the mid points of the boundary elements and the position of the point where the effect is calculated (i.e., length and density): if the number of boundary elements is increased it will change the final form of the modeled structure, therefore, in running the program, the number of elements is increased until no more significant changes in the result are observed.

Shear stress is sensitive to s_1/s_3. The displacement discontinuity D_s can be derived from stratigraphic relations, seismic reflection profiles, etc. Elastic thickness of the modeled crust is a function of Young's modulus; it determines plate rigidity and hence lateral effect of deformation. The greater the modulus value, the more elastic the behavior, hence the wider the range of deformation. Therefore, choice of E is significant when looking for a "best fit" for width of structure and hanging and footwall tilts.

The model cannot be tested against other models directly, since other models may involve assumptions not amenable to the numerical methods utilized in the program. Testing, therefore, consists of "goodness of fit" to the observed geological/geophysical/topographic observations at broad scales. The result can help determine if a different model is necessarily required to explain deformation given reasonable parameters utilized by the boundary element model.

Upgrades to the computer program may deal with the following: iterative computations to eliminate grid overlaps developed during fault distortions, particularly creation of an algorithm to deal with curved faults. Presently, erosional cutting of footwalls and filling of basins is not actually computed -- this must be done by inspection; the model assumes that erosion rate equals the deposition rate (i.e., footwall erosion is the only source of deposition on the hanging wall. Only long-wavelength and large fault deformations are presently modeled.

The initial plan is to examine conventional regional models, both descriptive and quantitative, and to experiment with the simplest models that capture the basic tectonic features of Yucca Mountain. The basic models include:

1. Models of normal faulting, such as faulting at Yucca Mountain and elsewhere in its geologic setting (i.e., Basin and Range structures).

2. Models that consider Yucca Mountain to be involved with shear associated with the Walker Lane and that consider strike-slip faulting elsewhere in the geologic setting.

3. Models that consider normal and strike-slip faulting to be shallow crustal structures controlled by simple unifying structures at depth (e.g., detachment faults and master transcurrent shears).

These models are to be treated in a context ranging in scale from the entire Great Basin to Yucca Mountain itself. Additional 3-dimensional dynamic modeling localized at Yucca Mountain may be conducted. This modeling will also account for isostatic effects associated with sediment loading and erosion and complex, multi-strand fault patterns. To the extent possible, complex and realistic parameters will be applied to regional simulation also, but increasing parametric complexity, being expensive and time consuming, will be guided by behavior of simpler simulations. Boundary element modeling can help evaluate (reconstruct as well as predict) the evolution of a deformation pattern within a large area, and relate the pattern to a small area (i.e., Yucca Mountain), thus aiding the interpretation of increasingly detailed data sets within a regional context; the technique thus contributes to a synthesis of tectonic processes at the site.

2.1.1 Rationale for the types of syntheses selected

Syntheses of geological or geophysical data are typically provided in the form of maps and cross sections, which conveniently show three-dimensional data symbologically and pictorially such that geometric and chronologic relationships among tectonic elements are made clear. However, because maps are symbological, a full synthesis must be accompanied by one or more texts that discuss or explain features and relationships shown by the maps. Three kinds of documents are to be provided by this activity: (1) geophysical maps and sections, (2) geologic maps and cross sections, and (3) summary tectonic maps and topical reports on tectonic processes or subprocesses.

<u>Geophysical maps and sections</u>

A variety of geophysical data that indicate distribution of crustal properties or processes and the geometry of buried structures will be used. These data include potential field data (gravity and aeromagnetic maps), spectral reflectance and surface backscatter data (remote sensing images), crustal profile data (gravity profiles, seismic reflection/refraction profiles), geodetic

data, well-derived data including heatflow and strain data, and magnetotelluric, electromagnetic, and resistivity data. These data are conveniently depicted as maps or profiles that can be overlaid or otherwise superimposed on geologic map or profile data for direct scale-compatible evaluation.

Geologic maps and cross sections

Geologic maps show the distribution of rock units, faults (particularly faults having a history of Quaternary movement and those that could represent potential sources of ground shaking within 100 km of the site), and other structures at the surface. Accompanying cross sections show inferred structure to variable depths in the subsurface. Distribution of the rock units and structures reflects the succession of geologic processes and indicates controls on such hydrologic features as ground-water flow paths, rates of flow, and water table elevations.

Topical reports on tectonic processes or subprocesses

Topical syntheses of rates, ages, locations, and descriptions of each identified process are needed to understand the nature of the process and to predict future locations and rates of the process. Results of a scoping study of the boundary element modeling technique applied to the Yucca Mountain region will be provided as a topical report. Topical reports will include the areas covered by accompanying maps. The tectonic maps will depict tectonic elements such as faults, igneous features, folds, earthquake data, and areas of uplift and subsidence.

2.1.2 Rationale for selecting the number, location, scale, duration and timing of syntheses

2.1.2.1 Number

The topical syntheses must cover the tectonic processes and subprocesses active at Yucca Mountain or within the geologic setting of Yucca Mountain during Quaternary time. The overlapping processes that have been identified include volcanism, igneous intrusion, folding, seismicity, faulting, uplift and subsidence, and lateral strain. Faulting is divided into four styles, corresponding approximately with subprocesses: right-lateral strike-slip faulting, left-lateral strike-slip faulting, normal and oblique faulting, and detachment faulting. Characterization of particular faults (and determination as to whether the faults are segmented, imbricated, or have a history of episodic movement) is the purview of individual site characterization studies that address specific areas or zones or kinds of faulting. The tectonics modeling study will synthesize these data in order to determine the pattern and sequence of fault deformation through time, derive a mechanistic relationship among classes of faults throughout the Yucca Mountain area, and arrive at an explanation of the fundamental causal impetus to all faulting. Tectonic models will not be evaluated on the basis of the relative importance that is given to one or another group of faults during characterization, but rather on how effectively a model explains the known history and behavior of each structurally defined group of faults. A model that

explains the north-south faults but fails to provide a reasonable explanation for the known record of other sets of spatially related or proximal faults will be rigorously weighted against alternative models. For purposes of modeling, faults will be categorized according to orientation, spatial distribution, style of displacement and structural geometry.

2.1.2.2 Location and scale

Geophysical maps and sections

Gravity and aeromagnetic synthesis maps at two scales are required. One map at 1:500,000-scale encompasses the geological setting of Yucca Mountain. The map is to be derived from regional USGS aeromagnetic and gravity compilations, so the actual map boundaries can be adjusted as work progresses. A more detailed isostatic anomaly map and aeromagnetic map at a scale of 1:250,000 will center on Yucca Mountain to provide more information on the relationship of Yucca Mountain to adjoining terranes and structural domains. This latter map will cover the area bounded by 115°45'W-117°00'W; 36°15'N0-37°30'N. Data are derived from the Pahute Mesa, Beatty, Death Valley Junction, Pahranagat Range, Indian Springs, and Las Vegas 1:100,000 USGS data sheets. The map area includes the Plio-Pleistocene basaltic eruptive centers within 35 km of the potential repository, and the parts of the Alkali Flats-Furnace Creek, Oasis Valley, and Ash Meadows ground water subbasins up-gradient from the potential repository (fig. 1-1). Additional geophysical data include remote sensing images, crustal profile data, geodetic data, borehole-derived data including heatflow and strain data, and magnetotelluric, electromagnetic, and resistivity data. These data are conveniently depicted as maps or profiles that can be overlaid or otherwise superimposed on geologic maps for direct scale-compatible evaluation.

Geologic maps and cross sections

Geologic synthesis maps will be generated at 1:250,000 and 1:500,000 scales, identical in projection and location with the areas of geophysical synthesis outlined above. A geologic map of the Yucca Mountain region, at a scale of 1:500,000 is required to provide regional context for geologic processes operating at or in the vicinity of Yucca Mountain and within its geological setting. These two maps will also show the distribution of faults known or inferred to have been active during Quaternary time, and which therefore could influence seismic design. The fault data included in the geological synthesis will be derived from the map of Quaternary faults located within a 100 km radius of Yucca Mountain). The geologic map of the Beatty 1:100,000 quadrangle will be used to depict Quaternary surficial deposits. The Beatty surficial geologic map will aid in estimation of Quaternary slip rates, and rates of other geologic processes, through correlation of dated Quaternary units within the Beatty 1:100,000 quadrangle with like or coeval units exposed at Yucca Mountain.

2.1.2.3 Duration and timing

Geophysical maps and sections

The geophysical synthesis maps of the Yucca Mountain site and adjoining areas described above and proposed in the SCP have been completed from data already available. The data can thus be used immediately. Other geophysical data, such as deep reflection profiling, magnetotelluric sounding, seismic refraction, electroresistivity, some remote sensing data, heat flow, geodetic leveling, have either not yet been obtained or are undergoing preliminary analysis within site specific studies. Such data, including data from the regional seismic monitoring network, will be incorporated into the data synthesis phase of this study in an ongoing and iterative process of data review and model refinement.

Geologic maps and cross-sections

Compilation of the geologic maps will be a continuing procedure during this activity. Early compilations are desirable to expedite characterization of the mapped features and to guide formulation of tectonic models in an evolving interpretive context. Early compilation will be based on (1) the geologic synthesis map of the Nevada Test Site at 1:100,000 (Frizzell and Shulters, 1990); (2) state geologic maps of Nevada at 1:500,000 (Stewart and Carlson, 1978) and California at 1:750,000 (Jennings, 1975, 1977). As with all geologic maps, addition of new data from field sources will lead to revisions and better integration of structure and rock units. Important sources of compiled and field data for mapped fault distributions include Activity 8.3.12.17.4.3 (Evaluate Quaternary faults within 100 km of Yucca Mountain, and Study 8.3.1.17.4.4 (Quaternary strike-slip faulting proximal to the site within northeast-trending fault zones). Revised rock units and their structural significance are reported in Study 8.3.1.17.4.5 (Detachment faults at or proximal to Yucca Mountain).

Topical reports

Topical reports on various tectonic problems or other issues relevant to the tectonic modeling study and to on-going geologic characterization will be prepared from time to time, as data warrant. Synthesis of seismic data will be updated and published periodically, in order to ensure effective use and communication to others of data accumulated by the Southern Great Basin Seismic net. Summary topical reports will be generated as the data gathering study on which they depend is completed.

2.1.3 Constraints: factors affecting selection of syntheses

Because this activity involves data compilation and analysis, the choice of methods was unaffected by impact on the potential site, any need to simulate repository operational conditions, or by interference with other tests, such as the design and construction of the exploratory study

facilities. The choice of methods is predicated on inclusiveness, variations in scale, multithematic integration, and the need to closely track and revise independent data sources and their interpretive constraints. With regard to accuracy and precision, limits and capability of analytical methods, and scale of the phenomena to be measured, the planned syntheses were selected on the basis that they provide a satisfactory and reliable means for achieving the objectives of the activity. The primary guiding factor in synthesis is the need for data to support models designed to simulate and predict tectonic processes.

2.2 Activity 8.3.1.17.4.12.2 Evaluate tectonic models

The necessity for developing and evaluating tectonic models is discussed in section 1.2.

2.2.1 Rationale for the types of tests or analyses selected

Available slip rate data for all known faults, including data obtained from the site characterization studies, will be used in two ways: (1) to validate those models that seek to explain kinematic fault deformation within the geologic setting of Yucca Mountain, and (2) to refine or formulate one or more such models that have a predictive capability. Viable tectonic models are designed to rationalize present local and regional stress in the crust with both the Quaternary record of faulting, and with ongoing seismicity. Models that reasonably account for known slip rates in terms of present and Quaternary activity are conservative in that estimates of future fault activity based on these models will be in accord with geologically reasonable projections of stress magnitudes and orientations for the postclosure period. Section 1.2.7 (Use of tectonic models in assessment of design and performance) of the study plan will use tectonic models (1) to ensure that assumptions, inferences, and conclusions concerning tectonic processes that are important to design and performance of the repository are consistent with the entire data base; and (2) to ensure that uncertainty in the data, assumptions, and inferences concerning rates and nature of those tectonic processes that are important to design or performance of the repository is adequately reflected in conclusions about those processes.

The tectonic models to be considered should account for all deformation (including that attending igneous activity) over areas large enough to be characteristic of basin-and-range tectonism (i.e., the geologic setting of Yucca Mountain). The waste emplacement area is small, and its boundaries artificial, in this context. Thus, the models to be considered make no distinction between faults within and outside the waste emplacement area. The tectonic models will consider fault relations primarily on the basis of geometry, as determined by field mapping and geophysical data. Other relationships significant to tectonic modeling include style of deformation (e.g., normal versus strike-slip, dilational versus compressional, ductile versus brittle, etc.) and chronologic (i.e., younger-older displacement relationships). Tectonic models will take such relationships into account in recreating the development and progression of regional and local strain rates and local failure, compare this history to present stress/strain

relationships, and establish reasonable, conservative projections of future deformation rates and style.

The models will take into account data from the rock characteristics program as well as the hydrology program; thus, they will have broad geologic and site-performance relevance at local to regional scales. The models will be presented as groups of maps and 2-D diagrams (related in terms of chronology or evolution of events) and supporting explanations. Three types of analytical arrangement and discussion will be provided: (1) tabulation and discussion of alternative models, (2) formulation and discussion of models of Quaternary kinematic behavior in light of alternative models, (3) formulation and discussion of models of Pliocene and Quaternary volcanism in light of alternative models.

2.2.1.1 Tabulation and consideration of alternative models

This analysis involves updating and expansion of tables that list and compare tectonic models (SCP tables 8.3.1.8-7.-8, and 8.3.1.17-7, and -8) and the elements of those models (as defined in section 1.2). The number of plausible variations of tectonic models potentially applicable to Yucca Mountain is large, and that number changes as models are modified, added, or discarded. Hence, a systematic listing of models and model elements is to be maintained, along with annotations as appropriate. The models are needed by the analysis and assessment investigations in order to justify projection of deterministically or probabilistically estimated rates of tectonic processes into the future, and to justify the anticipation of future tectonic processes. The models will also be used in probabilistic hazard analysis, not only in the estimation of rates for the processes, but also for the local and regional zonation effects. The analysis and assessment investigations include Postclosure Investigations 8.3.1.8.1, -.2, -3 and -.4, and Preclosure Investigations 8.3.1.17.1, -.2, and -.3. A preliminary list of alternative tectonic models, including the basic model parameters, is given in Table 2-1.

2.2.1.2 Models of Quaternary kinematics, Yucca Mountain and Yucca Mountain region

This test involves formulation of kinematic models which seek to balance horizontal components of Quaternary movement on known and possible major faults within the Yucca Mountain region. These faults include the Stewart Valley-Pahrump-Stateline fault, the Death Valley-Furnace Creek fault, the Mine Mountain, Rock Valley and Cane Spring faults, the Bare Mountain fault, and the faults within the site area (figs. 1-1, 2-4, and 2-5). The purposes of this analysis are (1) to confirm that horizontal slip rates determined for individual faults are consistent with slip rates of other faults within the region and site area, and (2) to assist in assigning slip rates to Quaternary faults for which the slip rate cannot be estimated using deterministic methods, in order to aid seismic hazard analysis.

2.2.1.3 Models of Pliocene and Quaternary volcanism, Yucca Mountain and Yucca Mountain region

The study plan integrates Quaternary volcanism insofar as volcanism is an expression of tectonism and is a stress-related phenomenon. The location, timing, and source of basaltic volcanic eruptions or intrusions are relevant to aspects of larger scale tectonic features such as transtensional (oblique graben or half-graben) structures, fault or shear zone intersections, and strain fields developed along tectonic domain boundaries or within regional transition zones such as the Walker Lane. This study sees volcanism as a subset of tectonic phenomena symptomatic of regional to local strain. As such, models and probability studies of volcanism carried out in study 8.3.1.8.1.1 are to be integrated as process-specific models and data sets into the more comprehensive tectonic models that focus on regional fault interactions, seismic hazard evaluation, and other crustal stress and deformation related features. This test involves formulation and evaluation of models which account for the locations, rates and sequence of eruption, and compositions of Pliocene and Quaternary volcanic rocks within the geologic setting of Yucca Mountain. The purpose of this analysis is to evaluate the extent to which features which control the localization and timing of volcanism are present or not present at and in the vicinity of Yucca Mountain. Models of volcanism are a particular class of alternative models. The general approach to completion of the analysis parallels that adopted for alternative tectonic models, as outlined above. The practical objective is to ensure that sufficient site characterization data are being obtained to adequately investigate the question of magma bodies or magmatic processes in the crust beneath the Yucca Mountain area (Activities 8.3.1.8.1.1.2 and 8.3.1.8.1.1.3 and Investigation 8.3.1.8.5). The evaluation will weigh the likelihood of future volcanism at Yucca Mountain, given the model parameters and the known tectonic configuration.

2.2.2 Rationale for selecting the number, location, duration and timing of tests or analyses

2.2.2.1 Number

The three types of tests, or analyses, selected ensure development of a full range of alternative tectonic models as well as the systematic evaluation of all elements of those models.

2.2.2.2 Location

This activity is intended to systematically tabulate and evaluate tectonic models at two scales: (1) the Yucca Mountain region (1:500,000; fig. 1-1), and (2) Yucca Mountain and its immediate environs (1:50,000; fig. 2-5).

2.2.2.3 Duration and timing

This activity is expected to continue for the duration of the site characterization program. We expect that the process of hypothesis formulation and testing entailed in this activity will drive data gathering to a greater or lesser extent, and that the data gathered will be considered in hypothesis formulation and testing. It is likely that information gathered during site characterization will necessitate modification, rejection, and possibly invention of new models, and that, in turn, will necessitate modification of the characterization program. Thus, this activity will provide coordination among the characterization studies and generate positive feedback as well.

2.2.3 Constraints: factors affecting selection of tests and analyses

Test selection for this activity was unaffected by potential impacts on the site, simulation of repository conditions, or interference with other tests, or the design and construction of exploratory study facilities. The planned methods are applicable in terms of the limits, capabilities, accuracy and precision of the tests and analyses to be performed to achieve the objectives of the activity. The factor of timing is described in section 2.2.2.3, and the consideration of alternatives is discussed in section 2.2.1.1.

2.3 Activity 8.3.1.17.4.12.3: Evaluate tectonic disruption sequences

The necessity of developing scenarios and the role of tectonic disruption sequences in those scenarios is discussed in section 1.2.

2.3.1 Rationale for the types of analyses selected

Only one task is planned as part of this activity, namely, the cataloging and evaluation of tectonic disruption sequences. A tectonic disruption sequence is a plausible succession of postulated tectonic events that could lead to disruption, in one form or another, of engineered or geologic barriers or facilities at the potential repository, or otherwise impair the capability of the repository to isolate waste. Tectonic disruption sequences are components of nine of the fifteen scenarios that were formulated by a panel of experts convened by the DOE (SCP, p. 8.3.5.13-26 and Table 8.3.5.13-1). Scenarios are "what if" situations that must be anticipated in order to estimate future repository performance (see SCP, Section 8.3.5.13, Total system performance). Therefore, in order to evaluate repository suitability and performance, it is important to provide a proper evaluation of possible tectonic disruption sequences that could figure in the development of each of the nine scenarios that involve tectonics. These nine scenarios are listed as follows:

Scenario	Description
2	Unexpected features (repository-induced subsidence or uplift, undetected fault zones, undetected significant lateral variations, undetected dikes or sills, undetected vertical heterogeneity, and "other")
5	Movement on a large fault inside the controlled area but outside the repository
6	Movement on a large fault within the repository
7	Movement on a small fault inside the controlled area but outside the repository
8	Movement on a small fault within the repository
9	Movement on a large fault outside the controlled area
10a	Extrusive magmatic event that occurs during the first 500 yr after closure
10b	Extrusive magmatic event that occurs 500 to 10,000 yr after closure
11	Intrusive magmatic event

Additionally, Ross (1987) identified 84 sequences of events and processes that could influence the performance of the repository. Of these, six involve tectonic disruption sequences, as follows (see SCP, pp. 8.3.5.13-28 through -42):

Ross Sequence Number	Description
12	Movement of a new or existing fault shears canisters along the line of the fault. The same fault also creates a "trap" for moisture moving laterally through the Tiva Canyon welded unit, and so the sheared canisters are placed in a region of enhanced downward moisture flux.
13	Fracture dilation along a new or existing fault creates zones of enhanced permeability in the Calico Hills and Paintbrush nonwelded units. Erosion of an arroyo at the surface and increased hydraulic conductivity of the Paintbrush unit create a zone of increased percolation along the fault. Moisture moves through fractures along the fault.

Ross Sequence Number	Description
14	The downdip side of a new or existing fault moves up. The fault thus forms a "trap" for laterally moving moisture in the Tiva Canyon welded unit. A new region of enhanced flux through the Topopah Spring unit is created.
15	Fracturing along a newly mobilized fault creates a permeable pathway through the flow barrier north of the repository block. The magnitude of the resulting change in the flow system is sufficient to raise the water table under the repository to the top of the Calico Hills nonwelded unit.
16	As in sequence number 15, fault-caused fracturing breaches the flow barrier north of the repository block. Flow is blocked by another barrier, not apparent from the current head distribution, and the resulting rise in water table floods the repository. The water passing through the repository discharges through springs in Fortymile Wash.
24	A basaltic volcano erupts through the repository. The volcano is fed through a dike; waste canisters within the dike mix with the magma, and their contents are erupted.

The lists above are not complete. Conspicuous by their absence are disruption sequences that involve coeval movement on several or many of the major faults at Yucca Mountain (see Ramelli and others, 1988; Fox and Carr, 1989), and those involving incremental strain within the upper plate of detachment faults (see Fox et al., in press). According to the SCP (p. 8.3.5.13-25), the DOE "has correlated the selection of scenarios with the results of evaluations of alternative conceptual models of site behavior". It follows that as models evolve, are discarded, or are newly proposed, scenarios must also be modified. Further, actual calculation of performance on the basis of the scenarios also requires information on the probability of occurrence of the scenario.

For these reasons, this activity will continue developing tectonic disruption sequences. That development entails two obligations, (1) identification and clarification of tectonic disruption sequences (in concert with development of alternative tectonic models), and (2) evaluation of tectonic disruption sequences in terms of specific location, nature of geologic and environmental influence, and estimation of probability of occurrence. However, consideration of the manner in which the disruption sequences could affect repository performance is delegated to applicable performance and assessment investigations. The performance and assessment investigations include Postclosure Investigations 8.3.1.8.1, -.2, -.3 and -.4, and Preclosure Investigations 8.3.1.17.1, -.2, and -.3.

2.3.2 Rationale for selecting the number, location, duration and timing of analyses

2.3.2.1 Number

One continually updated analysis is considered sufficient because only one task is planned for this activity (i.e., cataloguing and evaluation of tectonic disruption sequences). The analysis will be conducted on an iterative basis -- each disruption sequence will be reviewed as new data are acquired and tectonic models are evaluated.

2.3.2.2 Location

Tectonic disruption sequences relate to both local and regional alternative tectonic models. They thus encompass the site area, prospective controlled area, and the geologic setting of Yucca Mountain.

2.3.2.3 Duration and timing

This activity will continue in concert with the development of alternative conceptual tectonic models for the duration of the site characterization program. The rationale parallels that given in section 2.2.2.3.

2.3.3 Constraints: factors influencing selection of tests and analyses

The discussion in section 2.2.3 is applicable to this section

3. DESCRIPTION OF TESTS AND ANALYSES

3.1 Activity 8.3.1.17.4.12.1: Evaluate tectonic processes and tectonic stability at the site.

The objectives of this activity are to:

- Synthesize potential field studies at Yucca Mountain and vicinity; define areal variations in anomaly patterns and amplitudes, and attribute them, using standard techniques as appropriate, to geologic features, such as lithologic units, faults, and intrusive bodies, relevant to local and regional tectonic models.

- Evaluate (1) the regional extent and crustal geometry of detachment faults, wrench faults, volcanic rocks belonging to the hypothesized Death Valley-Pancake Range belt; (2) caldera model for Crater Flat; (3) regional pattern of oroclinal bending (oroflexing); (4) the regional extent of Miocene ash-flow tuffs and associated pyroclastic and epiclastic rocks; (5) regional extent of Paleozoic rocks known to be aquifers or aquitards, or that provide favored surfaces of detachment faulting or thrusting; and (6) pull-apart/strike slip mechanisms as cogenetic features of detachment.

- Synthesize and evaluate information pertaining to possible Quaternary wrench faulting in the Walker Lane (Las Vegas to Cedar Mountain) and evaluate pull-apart/strike slip models for Crater Flat; constrain, if possible, the rate of offset and recurrence interval of potentially significant faults (including the Bare Mountain fault and faults analogous to those near Cedar Mountain); and evaluate the applicability of this information to geologic hazards at the site. Boundary element modeling may contribute to this objective.

- Synthesize and evaluate information pertaining to detachment faults at Yucca Mountain and vicinity, and constrain, if possible, the rate of displacement, subsurface configuration, and character of risk posed by this class of faults.

- Synthesize and evaluate information pertaining to normal (and north-trending oblique and strike-slip faults) at the site and vicinity, and constrain, if possible, aggregate strain rate, subsurface configuration, recurrence interval, and character of risk posed by this class of faults. Boundary element modeling may contribute to this objective.

- Synthesize and evaluate information pertaining to the northeast-trending left-lateral strike-slip faults in the Nevada Test Site and vicinity, and constrain, if possible, slip rate, recurrence interval, and character of risk posed by this class of fault. Boundary element modeling may contribute to this objective.

3.1.1 General approach

This activity will focus on preparation of synthesis maps and reports utilizing existing data and data to be produced during site characterization. Three types of synthesis are required: (1) geophysical data, (2) geologic synthesis maps, and (3) topical reports on data and tectonic processes or subprocesses. Rationale for selecting these maps and synthesis reports are discussed in section 2.1.1. Scale and desired areal and topical coverage is discussed in section 2.1.2.2.

3.1.1.1 Geophysical data

Previously published data are to be compiled at 1:100,000 scale. The following synthesis maps are required:

(1) Bouguer gravity maps of the Beatty, Pahute Mesa, Pahranagat, and Indian Springs quadrangles at 1:100,000 scale.

(2) Aeromagnetic maps of the Beatty, Pahute Mesa, Pahranagat, and Indian Springs quadrangles at 1:100,000 scale.

(3) Bouguer gravity map and aeromagnetic map of the Nevada Test Site at 1:100,000 scale. These maps have been completed and published: Kirchoff-Stein et al. (1989); Ponce et al., (1988).

3.1.1.2 Geologic synthesis maps

The following geologic synthesis maps are required:

(1) Yucca Mountain region at 1:500,000 or greater scale. As noted in section 2.1.2.3, existing regional compilations of the geology of Nevada and California (Stewart and Carlson, 1978, and Jennings, 1975; 1977) provide a satisfactory synthesis map of the geologic setting of Yucca Mountain at 1:500,000 scale. This scale is compatible with the regional character of the tectonic models, and provides for adequate depiction of features in the context of the geologic setting. Data from all scales will be considered as necessary in synthesis, and the synthesis will be compiled at 1:500,000, or at 1:100,000 where detail is relevant.

(2) Beatty, Pahute Mesa, Pahranagat, and Indian Springs quadrangles at 1:100,000 scale. A geologic synthesis map of the Nevada Test Site at 1:100,000 scale (see SCP, p. 8.3.1.17-202) has been completed (Frizzell and Shulters, 1990). Synthesis of the Pahute Mesa, Pahranagat, and Indian Springs quadrangles at 1:100,000 scale, exclusive of the Nevada Test Site, is underway by the U. S. Geological Survey. As an adjunct to this activity, preparation of the Beatty 1:100,000 quadrangle is also underway by the U. S. Geological Survey. We expect that

these maps will satisfy the requirements for this activity and that they will be completed in a timely fashion.

Sources of Quaternary fault data, and the associated coverage, are as follows:

Area	Data	Source	Status
Area within 100km of Yucca Mountain, including the central part of Walker Lane	Photogeologic map of Quaternary scarps and lineaments, 1:100,000 scale	Activity 8.3.1.17.4.3.2	Reheis, 1991: Reheis and Noller, 1991
Ash Meadows area	Photogeologic map of Quaternary scarps and lineaments, 1/62,500 scale	Activity 8.3.1.17.4.3.2	Manuscript to be submitted September 1994
Death Valley	Death Valley-Furnace Creek fault zone	Activity 8.3.1.17.4.3.2	(Brogan and others, in press)
Yucca Mountain and Crater Flat	Quaternary fault map	Activity 8.3.1.17.4.6.1	Manuscript to be submitted September 1993
Southeastern part of Nevada Test Site	Mine Mountain, Cane Springs, Rock Valley fault zones	Study 8.3.1.17.4.4	Planned. Preliminary map of Rock Valley-Cane Springs fault zone to be submitted in Sept 1995

These data will be compiled on the geologic maps as fault traces and as lineaments of presumed and possible fault origin; sense of displacement (apparent offset), and probable age of most recent movement (i.e., Holocene, late Pleistocene, early and middle Pleistocene) will be shown where possible.

3.1.1.4 Topical syntheses of data on tectonic processes or subprocesses

This task involves preparation of reports that summarize data on tectonic processes operating during the Quaternary within the geologic setting of Yucca Mountain. Identified tectonic processes include volcanism, igneous intrusion, folding, seismicity, faulting, uplift and subsidence, and lateral strain (crustal dilations and compressions associated or unassociated with other processes enumerated above). Seismicity is treated as a distinct process, although it in fact is the expression of contemporary faulting, volcanism, or igneous intrusion. The stress field and

first motion analysis of earthquakes are important manifestations or symptoms of tectonic processes, hence warrant inclusion in the list of topics to be summarized.

Data to be synthesized are chiefly those developed by the tectonics investigations (Programs 8.3.1.8 and 8.3.1.17), but include relevant data from the rock characteristics investigations (Program 8.3.1.4), erosion program (Program 8.3.1.6), and paleoenvironmental history study (Study 8.3.1.5.1.4). Additionally, results of the boundary element modeling scoping study, and any follow-on applications of the technique, will be provided under this heading

Identified processes, and correlative syntheses and key sources of data are as follows:

Process (feature)	Synthesis	Key studies supplying data
Volcanism	Field data and geochronology for basaltic volcanic centers in the Yucca Mountain region	8.3.1.8.1.1 - Probability of magmatic disruption of the repository
	Scenarios of future magmatic activity at Yucca Mountain	8.3.1.8.1.2 - Physical processes of magmatism and effects on the potential repository
	Pliocene and Quaternary volcanism within the Death Valley-Pancake Range belt	8.3.1.8.5.1 - Characterization of volcanic features
Igneous intrusion	Heat flow and related features in the Yucca Mountain region	8.3.1.8.5.2 - Characterization of igneous intrusive features
	Seismic refraction profiles	8.3.1.17.4.3 - Quaternary faulting within 100 Km of Yucca Mountain, including the Walker Lane
Folding	Neogene folding within the Yucca Mountain region	8.3.1.8.5.3 - Investigation of folds in Miocene and younger rocks of region
Seismicity	Seismicity within the Yucca Mountain region	8.3.1.17.4.1 - Historical and seismicity
Stress field	Stress field at Yucca Mountain, and within the Yucca Mountain region	8.3.1.17.4.8 - Stress field within and proximal to the site area

Process (feature)	Synthesis	Key studies supplying data
Faulting (general)	Evaluation of fault geometries in upper crust from seismic reflection data	8.3.1.17.4.3 - Quaternary faulting within 100 Km of Yucca Mountain, including the Walker Lane 8.3.1.17.4.4 - Quaternary faulting proximal to the site within northeast-trending fault zones 8.3.1.17.4.7 - Subsurface geometry and extensions of Quaternary faults at Yucca Mountain
Right-lateral strike-slip faulting	Quaternary faulting within 100 km of Yucca Mountain, including the Las Vegas to Cedar Mountain segment of the Walker Lane	8.3.1.17.4.3 - Quaternary faulting within 100 km of Yucca Mountain, including the Walker Lane
Left-lateral strike-slip faulting	Quaternary faulting within northeast-trending fault zones	8.3.1.17.4.4 - Quaternary faulting proximal to the site within northeast-trending fault zones
Normal and oblique faulting	Quaternary normal-, oblique-, and strike-slip faulting within the site area	8.3.1.17.4.6 - Quaternary faulting within the site area 8.3.1.17.4.7 - Subsurface geometry and extensions of Quaternary faults at Yucca Mountain
Detachment	Detachment faulting at Yucca Mountain and vicinity	8.3.1.17.4.5 - Detachment faults at or proximal to Yucca Mountain 8.3.1.17.4.7 - Subsurface geometry and concealed extensions of Quaternary faults at Yucca Mountain
Uplift and Subsidence	Quaternary uplift and subsidence within the Yucca Mountain region	8.3.1.17.4.9 - Tectonic geomorphology the Yucca Mountain region 8.3.1.17.4.10 - Geodetic Leveling
Lateral Strain	Lateral strain (compression and dilation) within the Yucca Mountain	8.3.1.17.4.11 - Characterization of regional lateral crustal movement

Additionally, processes will be characterized on the basis of locale, rate of operation, and historical interaction with other processes or subprocesses.

3.1.2 Test methods and procedures

This activity summarizes and synthesizes existing data. No technical procedures are employed. A scientific notebook may be prepared in documenting application and results of the boundary element modeling scoping study.

3.1.3 Quality Assurance

Quality Assurance (QA) requirements for this activity have been specified in Yucca Mountain Project QA Grading Reports, which are issued as separate controlled documents. All procedures applicable to this activity will be prepared in accordance with applicable QA requirements.

3.1.4 Required tolerances, accuracy, and precision

No explicit requirements for tolerance, accuracy or precision have been specified for this activity. QA requirements for standard geologic field operations are appropriate for this activity.

3.1.5 Range of expected results

Because this is a synthesis that depends, in part, on an amount and quality of data yet to be obtained, no range of results and no end member results can be established at this time.

3.1.6 Equipment

No specialized equipment is used.

3.1.7 Data-reduction techniques

Existing map data at scales larger than the compilation scales specified in this activity (see section 2.1.2.2) will be generalized, photographically reduced, and plotted on scale-stable base material at compilation scales. Some data, especially geophysical data, are available in digital form and can be plotted on scale-stable base at any scale. Wherever possible, advantage will be taken of digital compilation and plotting techniques to incorporate recently edited or archival data.

3.1.8 Representativeness of results

Maps are intended to represent the general locations and relative ages of the Quaternary tectonic features. Synthesis reports are intended to describe and interpret the identity, locations, and rates of Quaternary tectonic processes and related features, and discussion of their importance to the program.

3.1.9 Relations to performance goals and confidence levels

See sections 1 and 4 for discussions applicable to this topic.

3.2 Activity 8.3.1.17.4.12.2 Evaluate Tectonic Models

The objectives of this activity are:

- Evaluate a range of tectonic models that relate the nature and estimated rates (including bounding values of those estimated rates) of Quaternary processes (including volcanism, faulting, uplift and subsidence, lateral strain, and possibly folding) of potential significance to design and performance of a repository at Yucca Mountain.

- Evaluate temporal changes in tectonic activity and resulting changes in style and extent of deformation, especially changes having potential hydrologic significance at and in the vicinity of Yucca Mountain. Compare tectonic models with respect to spatial relations, relative timing, and inferred or demonstrated cause-and-effect associations of component processes and effects.

- Ensure that assumptions, inferences, and conclusions concerning tectonic processes that are important to design and performance of the repository are consistent with tectonic models applicable to the site.

- Ensure that uncertainty in the data, assumptions, and inferences concerning rates and nature of those tectonic processes that are important to design or performance of a repository are adequately reflected in conclusions about those processes.

3.2.1 General approach

This activity includes three analyses or tests: (1) tabulation and evaluation of alternative models, (2) formulation of models addressing Quaternary kinematics relating to Yucca Mountain and the Yucca Mountain region, and (3) formulation of models addressing Pliocene and Quaternary volcanism at Yucca Mountain and in the Yucca Mountain region.

3.2.1.1 Tabulation and consideration of alternative models

This test involves assembling and analyzing alternative tectonic models and the elements of those models (as defined in section 1.2). Steps in this process include collocation of collected and project-generated models, and analysis and comparison (testing) of the models or model elements.

Study 8.3.1.17.4.12 Tectonic Models and Synthesis

The models and model elements typically are generated and proposed by project scientists who collect tectonics data, by industry and academic colleagues pursuing coordinated studies, and by scientists within regulatory bodies and oversight committees charged with review of project results. Thus, a variety of models of varying scope and precision will be considered. As stated in section 1, the models that will ultimately be developed for this study for direct application to performance assessment will be conceptual models presented as narratives. The conceptual models may derive some support from kinematic modeling, to the extent that kinematic modeling is feasible and applicable to the deformation features in and around Yucca Mountain. The conceptual models will also incorporate viable components of models that survive the analysis described below. Activity 8.3.1.17.4.12.2 assumes responsibility for both collection and analysis of the models. Analysis involves (1) separating the model into model elements, (2) testing, thus refuting or validating the model, through comparison of it, its corollaries, and its implied predictions with available data, (3) recognition of corollaries which can be falsified or validated through collection of key data, and (4) identification of features or processes not otherwise evident in the Quaternary record, but the presence of which is recognized as a corollary of a viable alternative model and therefore a test of its acceptability. The results of this process are comparative summaries that will be recorded through modification and expansion of SCP tables 8.3.1.8-7, -8, and 8.3.1.17-7, and -8. An accompanying text describing the evaluation process will be provided with the tables. This product will be upgraded in successive interim reports.

3.2.1.2 Formulation of models of Quaternary kinematics, Yucca Mountain and Yucca Mountain region

This analysis is essentially the same as that outlined in section 2.2.1.2. Required analytical parameters include location, orientation, direction of movement, and slip rates of faults. In this case, the primary interest is in the total rates of deformation or strain along a fault, so total slip on any fault segment will be averaged over the Quaternary Period to give a slip rate, or slip budget. The sum of the slip rates on major faults or fault zones will then be used to determine the rates of regional strain and to assess lateral and vertical components of distortion within the Yucca Mountain region during Quaternary time. This information can also aid in partitioning strain among tectonic elements that comprise the geologic setting of Yucca Mountain.Part of the required data is available in the published and unpublished record; part will be gathered during site characterization. Some data may derive from the boundary element modeling scoping study. The data will also be used to constrain local Quaternary fault block translation, dilation, and compression. Subject faults include the Stewart Valley-Pahrump-Stateline fault, the Death Valley-Furnace Creek fault, the Mine Mountain, Rock Valley and Cane Spring faults, the Bare Mountain fault, and other prominent faults within the site area (figs. 1-1, 2-4, and 2-5). Data on the Mine Mountain and Cane Spring faults is to be collected by Study 8.3.1.8.4.4 (Quaternary faults proximal to the site within northeast-trending fault zones), and for the Stewart Valley-Pahrump-Stateline fault by Study 8.3.1.8.4.3 (Quaternary faulting within 100 km of Yucca Mountain, including the Walker Lane).

3.2.1.3 Formulation of models of Pliocene and Quaternary volcanism, Yucca Mountain and Yucca Mountain region

This test involves formulation and evaluation of models which account for the locations, rates and sequence of eruption, and compositions of Neogene and Quaternary volcanic rocks within the geologic setting of Yucca Mountain. Models of volcanism are a particular class of alternative models. Appropriate models have been formulated by LANL under study plans 8.3.1.8.1.1, 8.3.1.8.1.2, and 8.3.1.8.5.1. These models relate the timing and localization of basaltic volcanism at Yucca Mountain to tectonic features -- i.e., detachment faulting, caldera structures, north-northeast-trending rifts and fracture zones, pull-apart basins, and structures related to alluvial basin formation or localization. Activity 8.3.1.17.4.12.2 will evaluate these models in a wider tectonic context. The purpose of this analysis is twofold: (1) to determine whether or to what extent the composition, character, and structural associations of volcanic features provide critical information on regional and local tectonic activity during the Quaternary, and (2) to determine the extent and nature of deep crustal tectonic activity and episodicity during the Quaternary. The general approach to completion of the analysis parallels that adopted for alternative tectonic models, as discussed above.

3.2.2 Test methods and procedures

This activity summarizes and synthesizes new and existing data. No technical procedures are employed.

3.2.3 Quality Assurance level assignment

The statements in section 3.1.3 are applicable to this section.

3.2.4 Required tolerances, accuracy, and precision

No explicit requirements for tolerance, accuracy or precision have been specified for this activity.

3.2.5 Range of expected results

The discussion in Section 3.1.5 is applicable to this section.

3.2.6 Equipment

No specialized equipment is used.

3.2.7 Data-reduction techniques

Existing data synthesized and summarized by Activity 8.3.1.17.4.12.1 (described above in paragraphs 2.1 and 3.1) will be used in this analysis. No specific data-reduction techniques are specified for this analysis.

3.2.8 Representativeness of results

Alternative models are intended to represent the full range of upper tier tectonic models (as described in section 2.2.1) applicable to Yucca Mountain and its geologic setting.

3.2.9 Relations to performance goals and confidence levels

See sections 1 and 4 for discussions applicable to this topic.

3.3 Activity 8.3.1.17.4.12.3: Tectonic disruption sequences

The objective of this activity is to evaluate disruption sequences that involve faulting, folding, uplift and subsidence, and volcanism, that are of potential significance to design or performance of the potential repository.

3.3.1 General approach

The sole task of this Activity is to catalog and evaluate tectonic disruption sequences. Sequences of tectonic events involving the tectonic processes summarized in Activity 1, the alternative models developed in Activity 2, and specific tectonic or geologic features (e.g., Windy Wash fault) will be tabulated. Evaluation will consist of (1) classification of the sequence of events as anticipated or unanticipated, and (2) consideration of the potential disruptive effect of the sequence of events on the engineered and geologic barrier system or on facilities important to safety. The extent to which regional tectonic processes or events can promote, initiate, or inhibit tectonic disruption sequences at or near the potential repository will be evaluated in terms of (1) supporting data, (2) results of model evaluation, and (3) direct comparison of mapped deformation features and those postulated for each disruption sequence. The regional models will support evaluation by providing the following constraints: (1) projected rates of strain or recurrence intervals for relevant fault movements, (2) likelihood and rates of controlling processes (e.g., rifting, detachment, regional strike-slip faulting), and (3) crustal structure and status of crustal processes, including melting, extension, flexure, uplift, etc. Evaluations are to be supported by explanatory notes, citations of relevant data and interpretations, and, where applicable, results of the boundary element modeling scoping study. Results will be reported in one or more topical reports that will include appropriate maps and comparative tables. The catalogue is intended to include disruption sequences suggested by the full range of alternative models.

3.3.2 Test methods and procedures

This activity interprets existing data; no technical procedures are employed.

3.3.3 Quality Assurance level assignment

The statements in section 3.1.3 are applicable to this section.

3.3.4 Required tolerances, accuracy, and precision

No explicit requirements for tolerance, accuracy or precision have been specified for this activity.

3.3.5 Range of expected results

Results will address the full range of alternative tectonic models as they pertain to the scenarios listed in section 2.3.1. Additional scenarios and/or disruption sequences may evolve, based on results of Activities 1 and 2. Because of present uncertainties in the range of anticipated data, a range of expected results cannot be defined.

3.3.6 Equipment

No specialized equipment is used.

3.3.7 Data-reduction techniques

Existing data synthesized and summarized by Activity 8.3.1.17.4.12.1 (described above in paragraphs 2.1 and 3.1), and alternative tectonic models developed in Activity 8.3.1.17.4.12.2 (described above in paragraphs 2.2 and 3.2), will be used in this analysis. No specific data-reduction techniques are specified for this analysis.

3.3.8 Representativeness of results

Alternative models are intended to represent the full range of tectonic disruption sequences applicable to Yucca Mountain and its geologic setting.

3.3.9 Relations to performance goals and confidence levels

See sections 1 and 4 for discussions applicable to this topic.

4. APPLICATION OF RESULTS

Information from this study will be used in the preclosure tectonics program (8.3.1.17), postclosure tectonics program (8.3.1.8), erosion program (8.3.1.6), and human interference program (8.3.1.9), geohydrology program (8.3.1.2), and rock characteristics program (8.3.1.4). Figures 4-1, 4-2, and 4-3, and Table 4-1 show what information from the study will be used and how that information will be used in specific studies in those programs. The following outline of where the information will be used is summarized from the SCP discussion of each activity.

Information from this study will be used in the preclosure tectonics program to:

- formulate a description of the regional hydrologic flow system (Activity 8.3.1.2.1.4.1)
- construct the site geologic model(s) and three-dimensional rock characteristic models (Studies 8.3.1.4.2.3 and 8.3.1.4.3.2)
- assess the potential for surface faulting at prospective sites of surface facilities important to safety (Activity 8.3.1.17.2.1.1)
- assess the potential for displacement on faults that intersect underground facilities (Activity 8.3.1.17.2.1.2)
- identify faults that could generate severe earthquake ground motion at the site; determine rates for earthquake recurrence as functions of magnitude (Studies 8.3.1.17.3.1; 8.3.1.17.3.5; 8.3.1.17.3.6)
- Assess the possibility for generation of new faults (Studies 8.3.1.17.2.1, 8.3.1.17.3.5, 8.3.1.17.3.6).

Information from this study will be used in the postclosure tectonics program to:

- evaluate structural relations between basaltic volcanism and fractures or faults (Activity 8.3.1.8.1.1.2)
- ensure that sufficient site characterization data are being obtained to adequately investigate the question of magma bodies or magmatic processes in the crust beneath the Yucca Mountain area (Activity 8.3.1.8.1.1.3 and Investigation 8.3.1.8.5)
- assess the likelihood of waste package rupture due to tectonic processes and events such igneous intrusion, faulting, or folding (Study 8.3.1.8.2.1)

- analyze the effects of tectonic processes and events on changes in water-table elevation (Study 8.3.1.8.3.2), local fracture permeability and effective porosity (Study 8.3.1.8.3.3), and rock geochemical properties (Study 8.3.1.8.4.1)

5. SCHEDULE AND MILESTONES

Figure 5-1 shows the schedule and principal milestones for Study 8.3.1.17.4.12 for FY 1995 and FY 1996. This information is abstracted from the most current and complete schedule network.

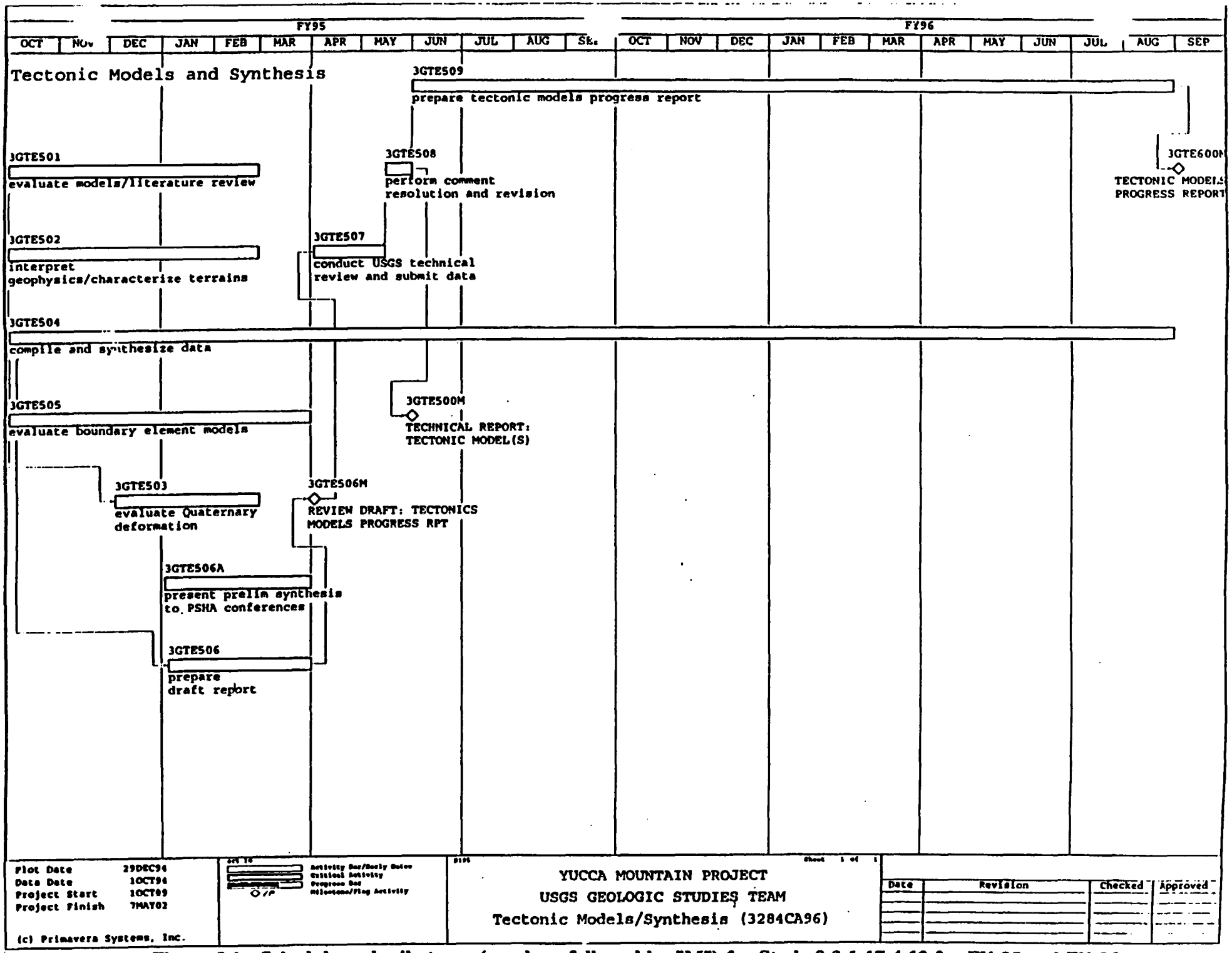

Figure 5-1. Schedule and milestones (numbers followed by "M") for Study 8.3.1.17.4.12 for FY 95 and FY 96

Rev. 1 6/8/95

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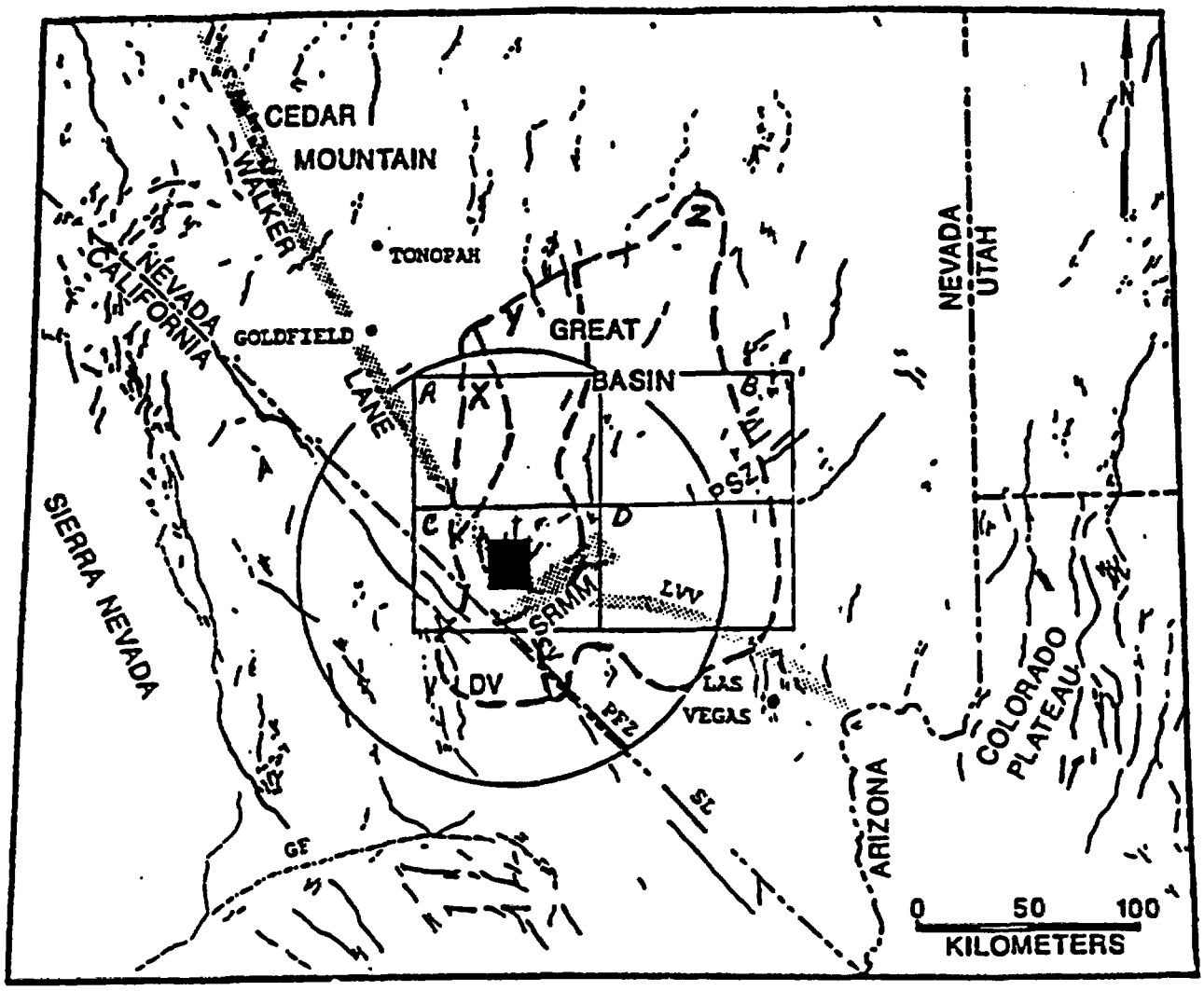


Figure 1-1. Index map of southern Nevada and adjacent parts of California, Utah, and Arizona, showing major Quaternary structural features. Potential repository site area at Yucca Mountain is indicated by the small black rectangle, and the large circle defines the area lying within 100 km of the site. Open rectangular areas are the boundaries of 1:100,000 quadrangles as follows: A - Pahute Mesa; B - Pahranagat Range; C - Beatty; D - Indian Springs. Heavy dashed lines define boundaries of ground water subbasins, as follows: X - Oasis Valley; Y - Alkali Flats-Furnace Creek; Z - Ash Meadows. Labeled fault and shear zones are: FC - Furnace Creek; DV - Death Valley; GF - Garlock; SV - Stewart Valley; PFZ - Pahrump; SL - State Line; LVV - Las Vegas Valley; SRMM - Spotted Range-Mine Mountain; PSZ - Pahranagat.

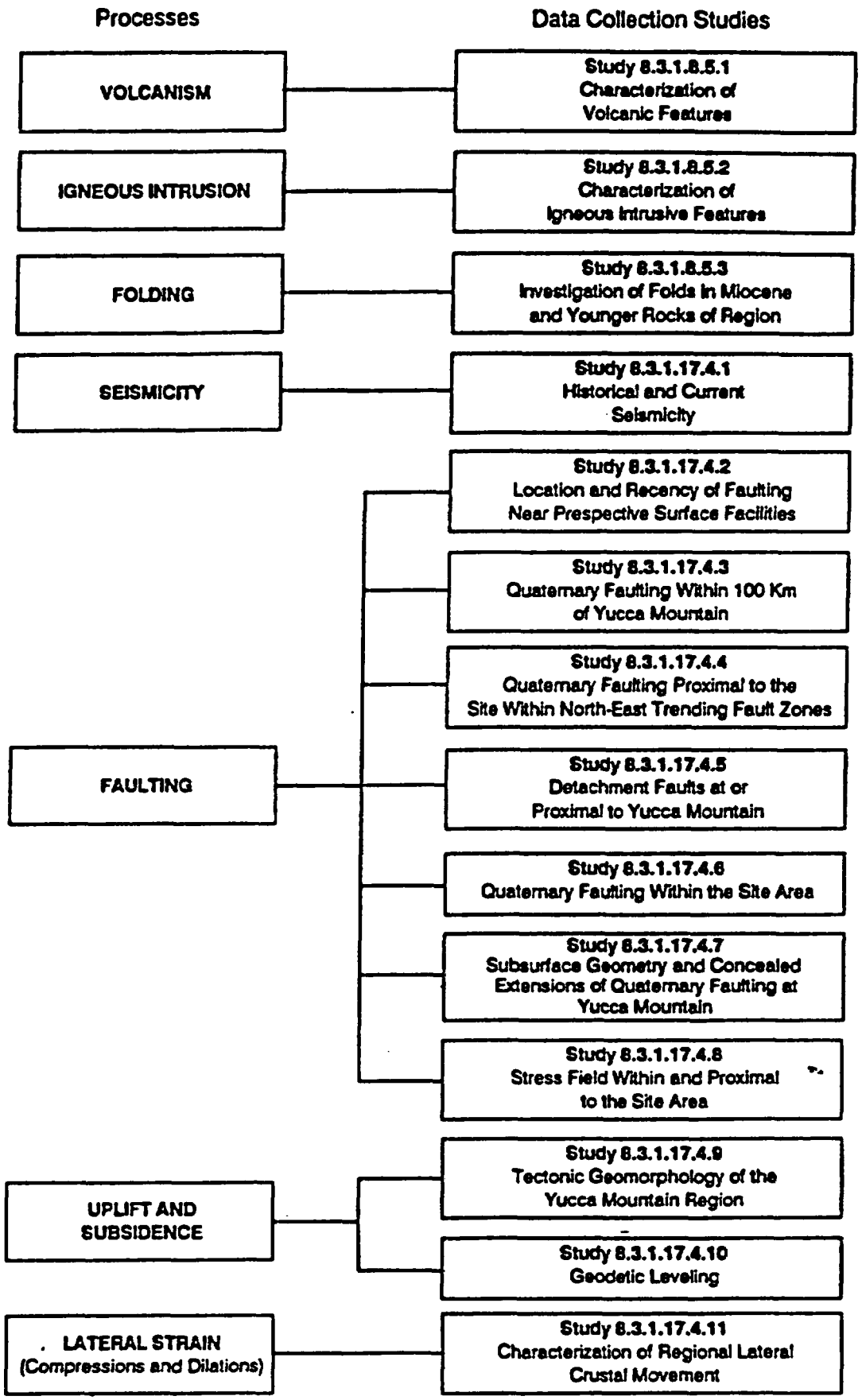


Figure 1-2. Tectonics processes and associated studies.

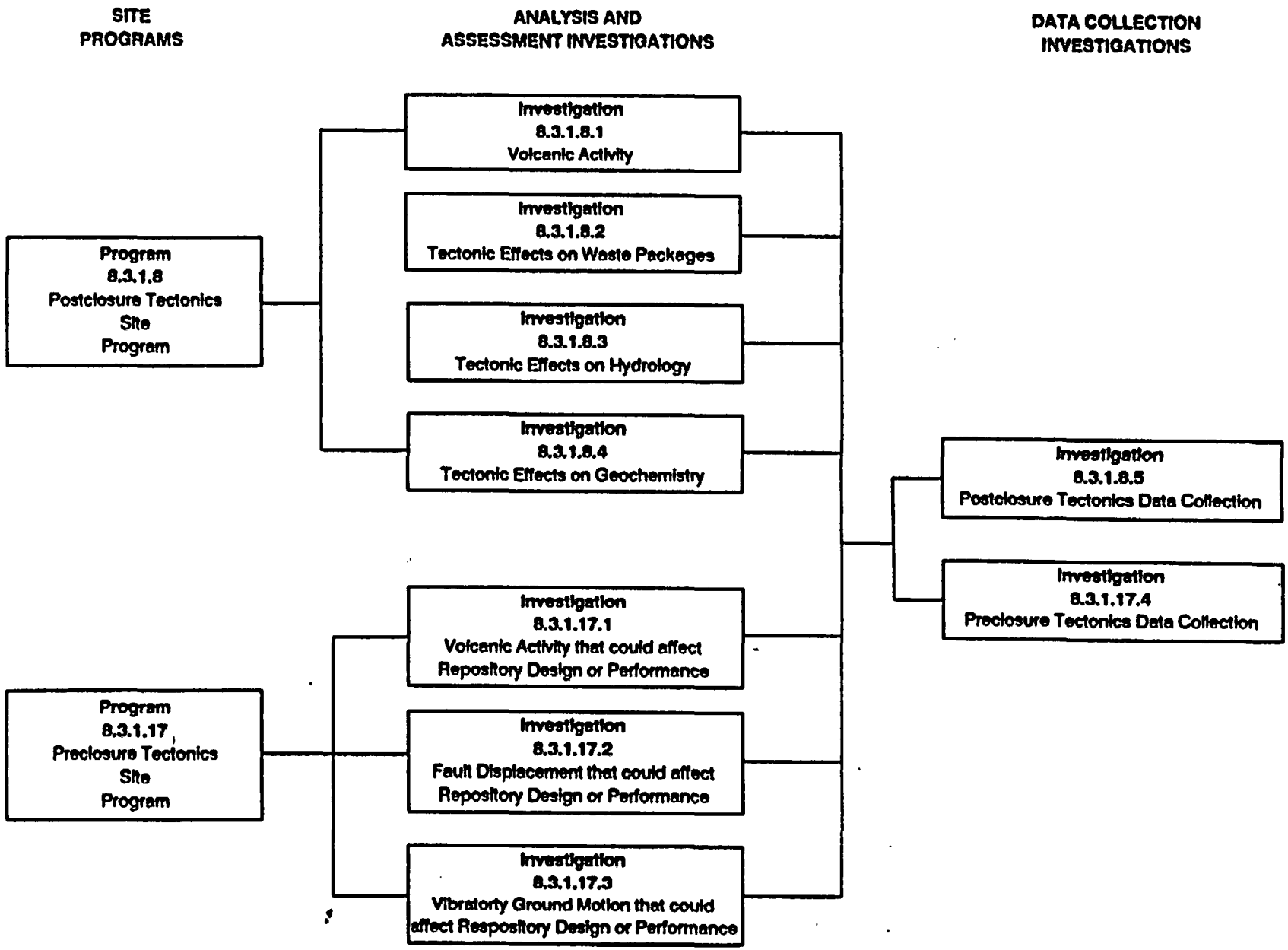


Figure 2-1. Organization of Tectonics Program

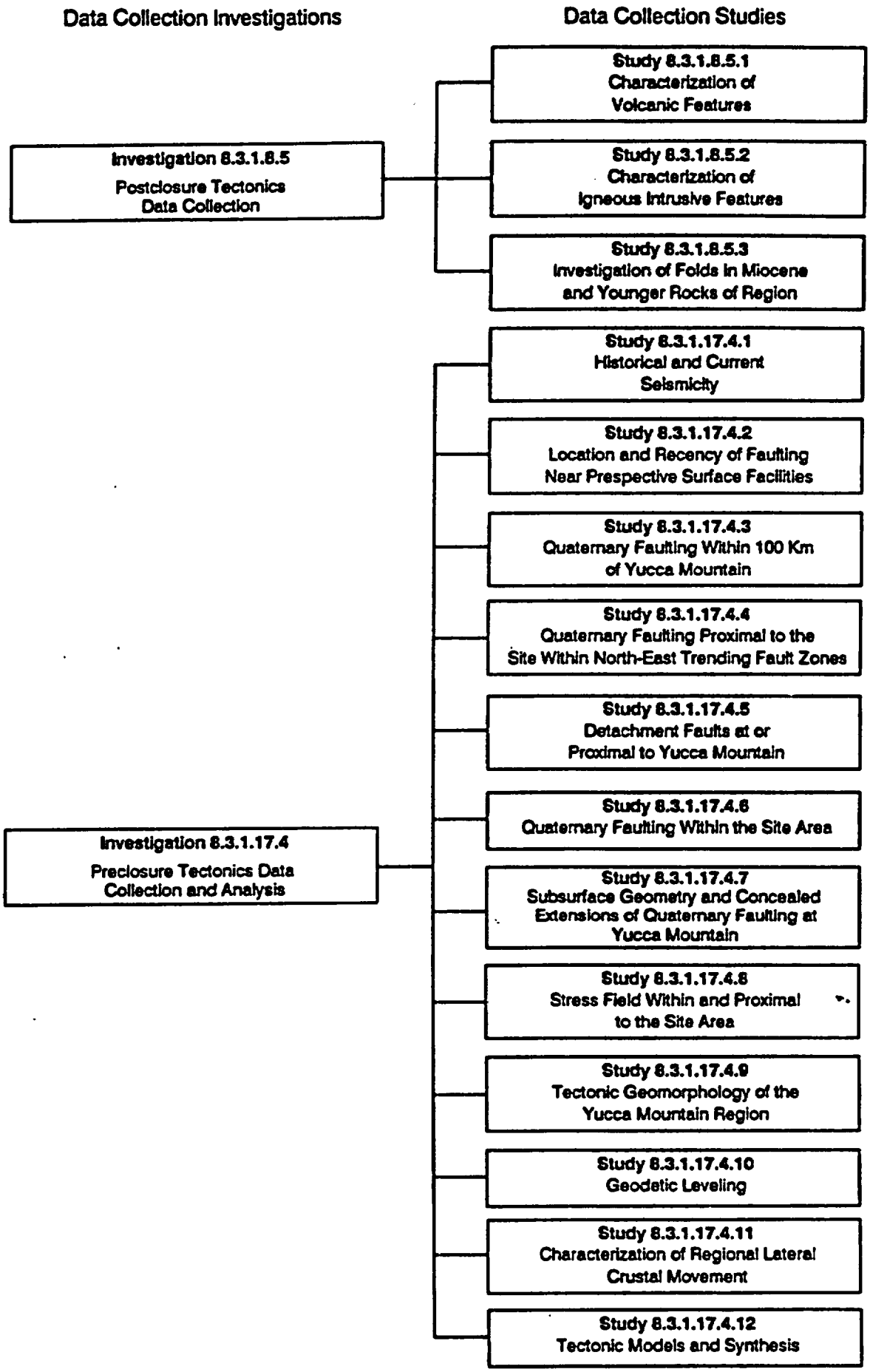


Figure 2-2. Organization of Tectonics Data Collection Investigations.

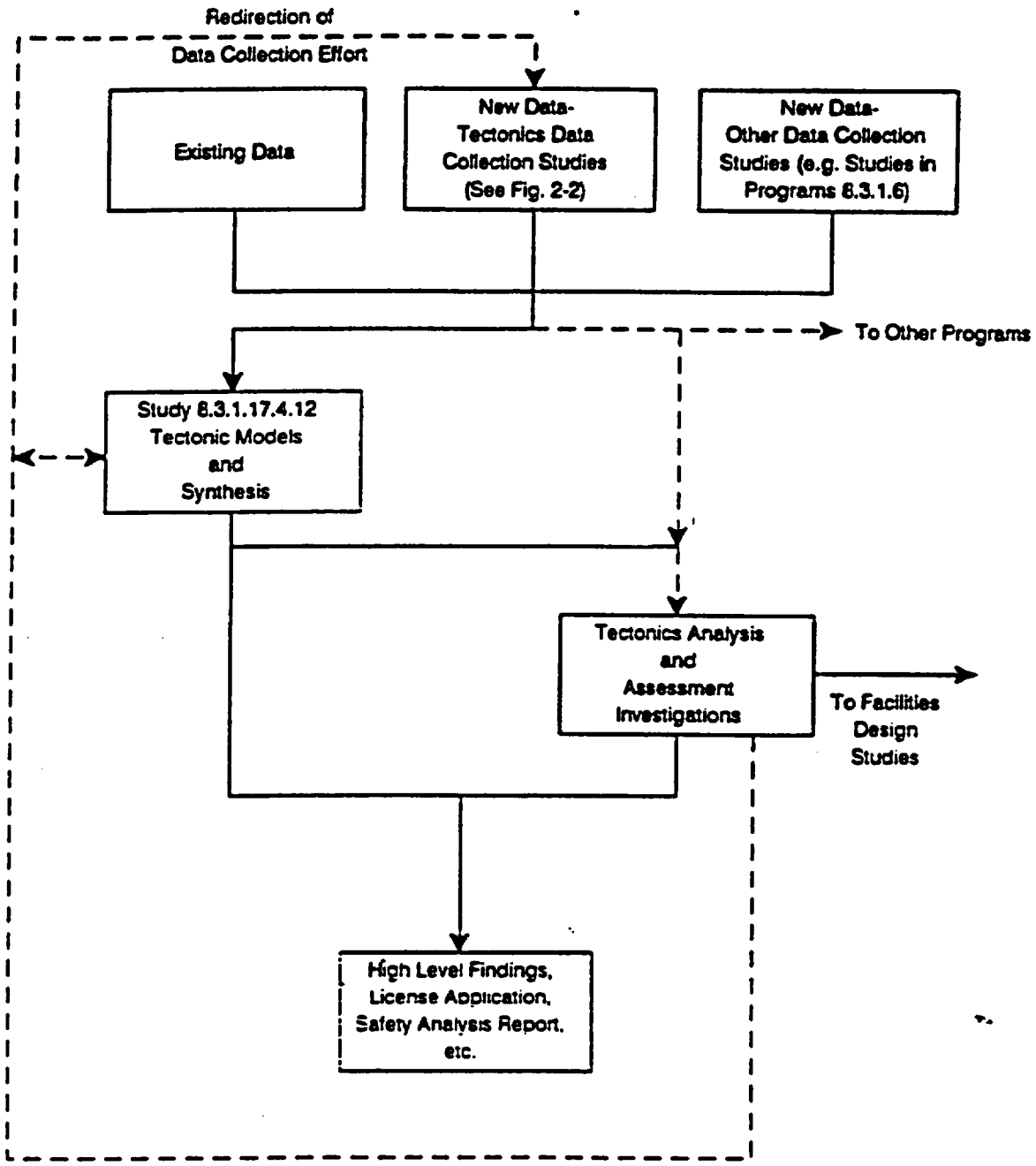


Figure 2-3. Flow of Information in Tectonics Program.

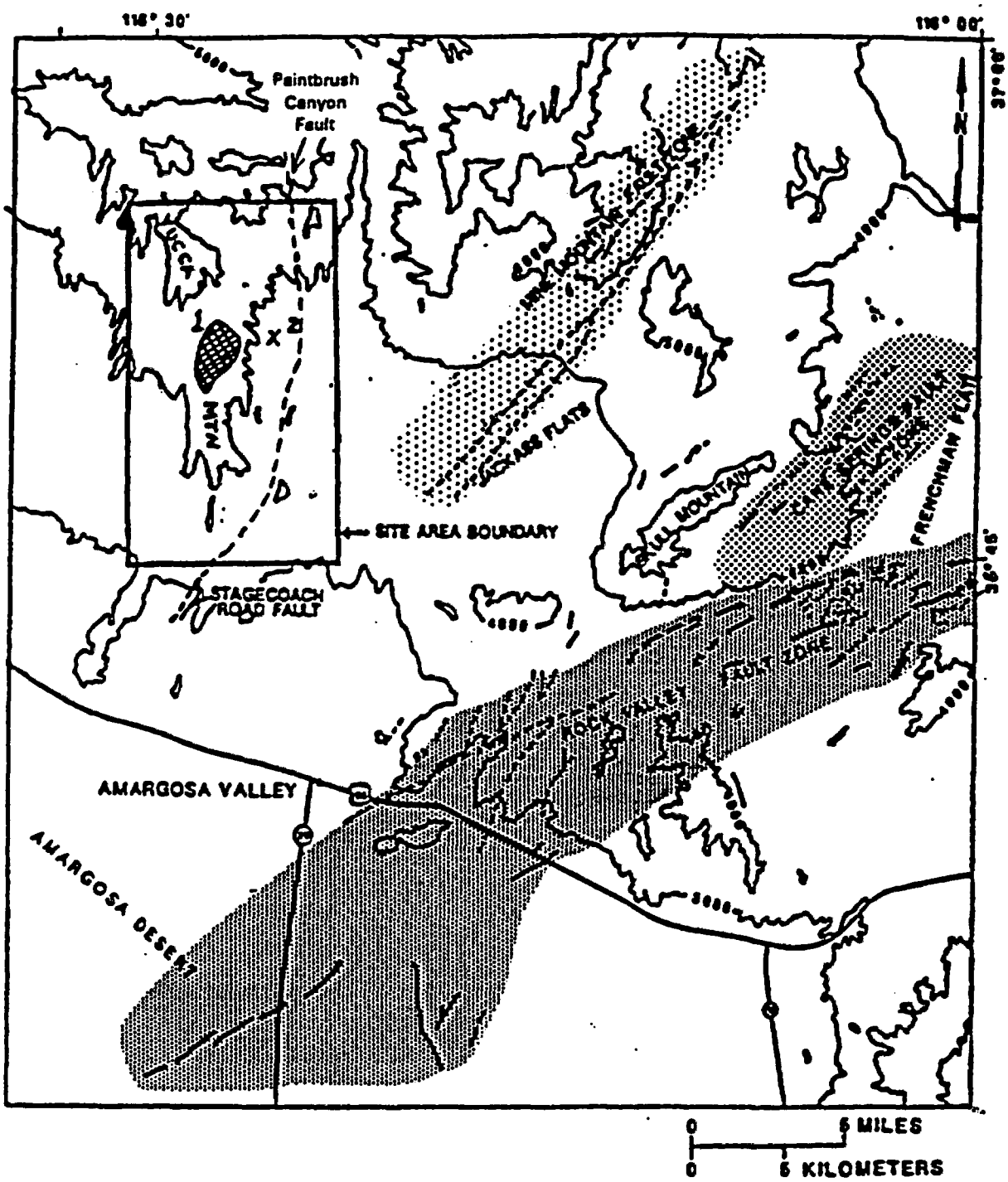
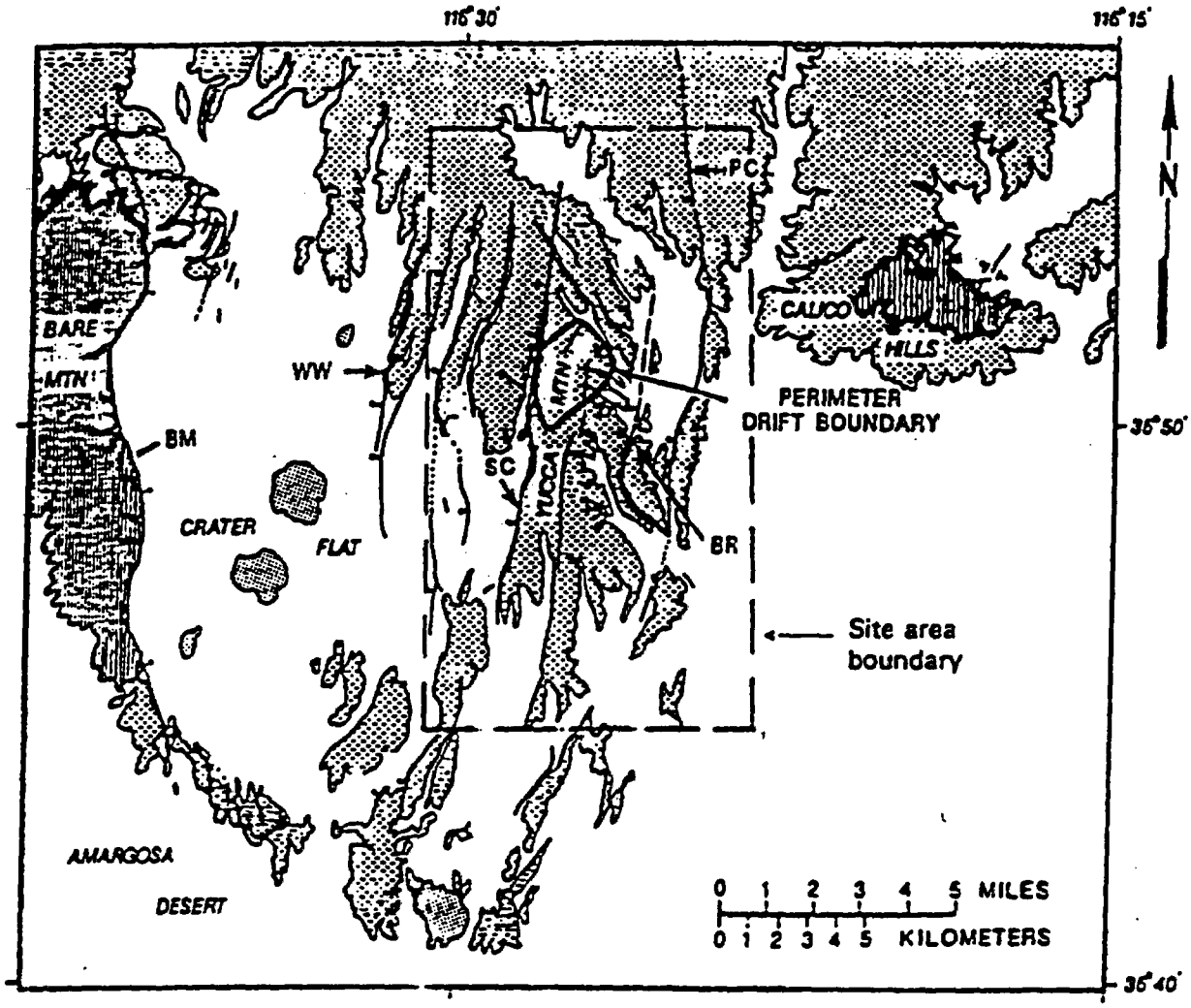


Figure 2-4. Index map showing location of the three northeast-trending fault zones being evaluated in Study 8.3.1.17.4.4. Numbered localities are: 1 - perimeter drift of potential repository site (cross hatch); 2 - proposed location of surface facilities (x). Stagecoach Road fault also shown.



QUATERNARY ALLUVIUM

QUATERNARY BASALT AND CINDER CONES

TERTIARY VOLCANIC ROCKS

PALEOZOIC ROCKS

FAULTS THAT OFFSET QUATERNARY DEPOSITS. DASHED WHERE UNCERTAIN. DOTTED WHERE CONCEALED

DETACHMENT STRUCTURES. DOTTED WHERE CONCEALED. TEETH ON UPPER PLATE

Figure 2-5. Quaternary normal faults and postulated detachment faults on and near Yucca Mountain. Modified from Swadley et al. (1984). BR - Bow Ridge fault; PC - Paintbrush Canyon fault: SC - Solitario Canyon fault; WW - Windy Wash fault; BM - Bare Mountain fault.

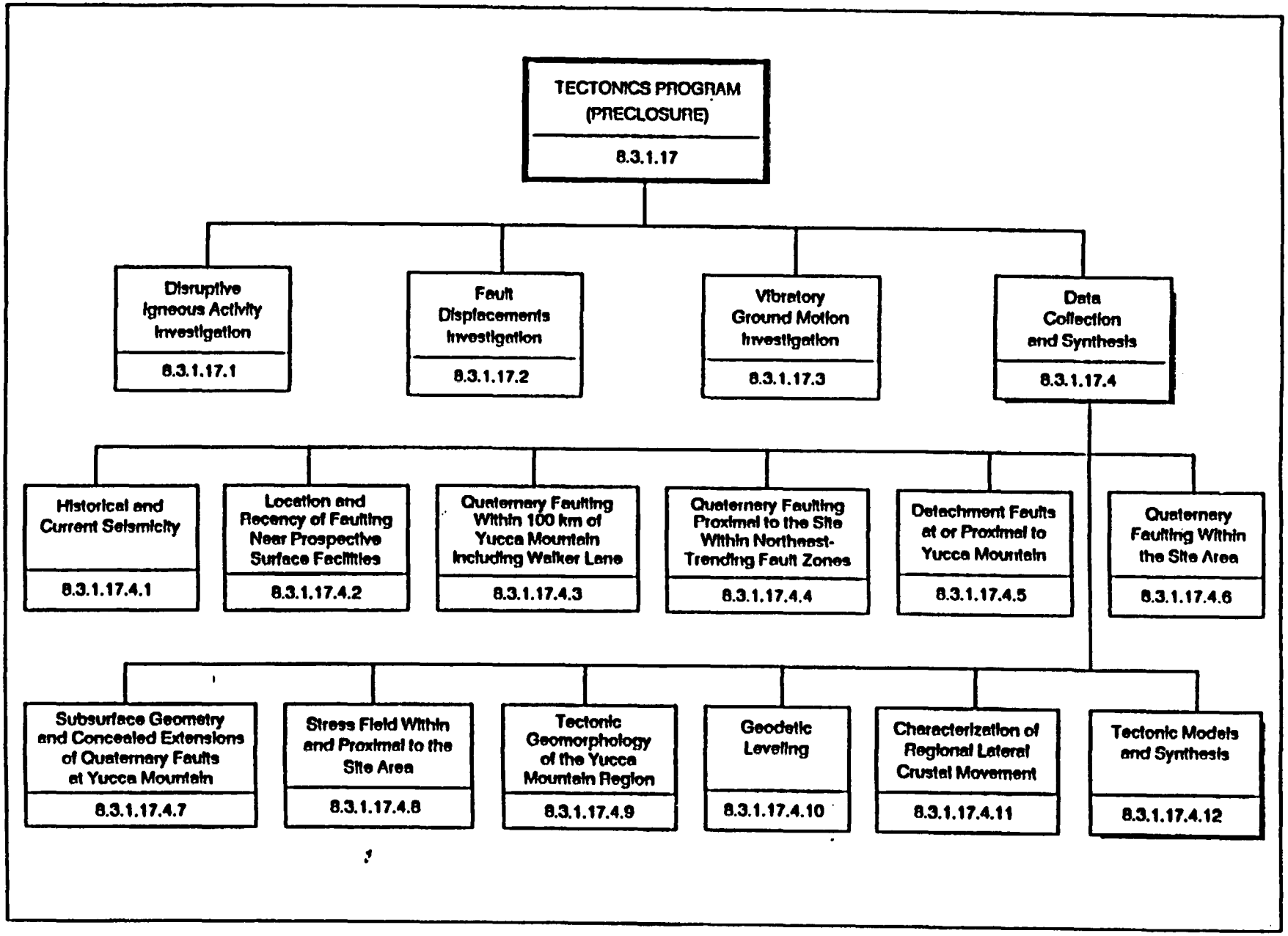
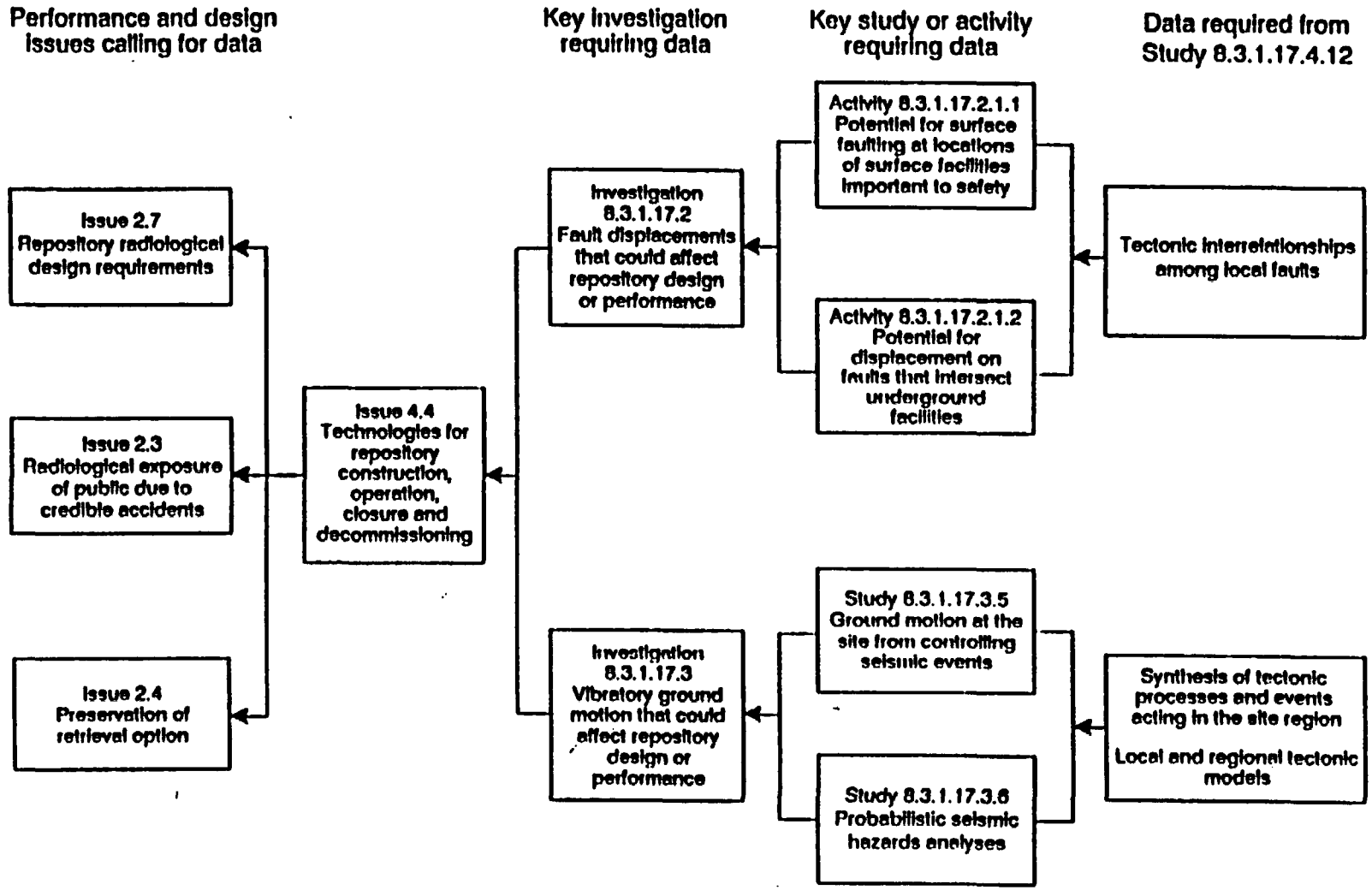


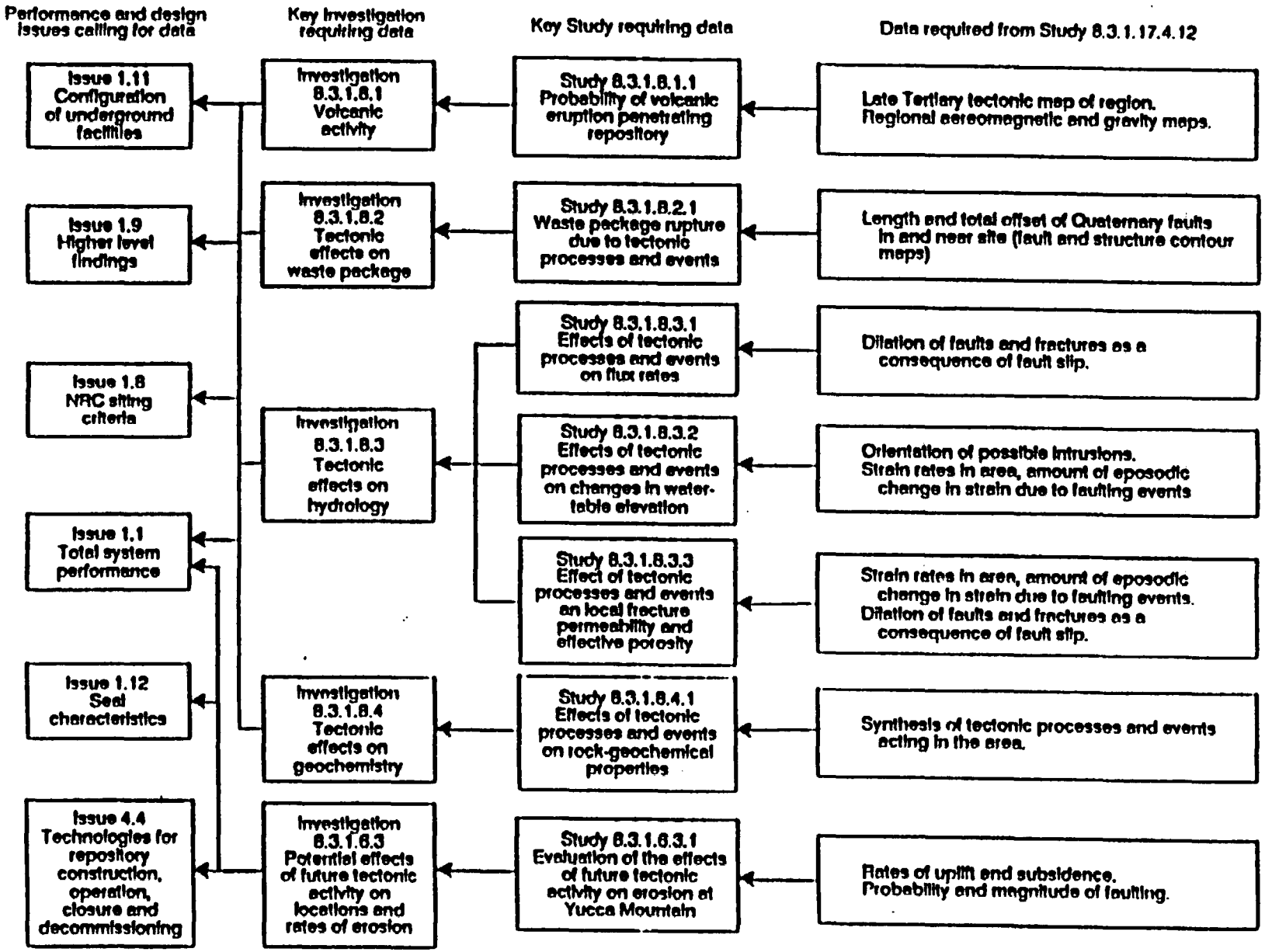
Figure 4-1. Relation of Study 8.3.1.17.4.12 to the preclosure tectonics program.



Sources of information:

for Investigation 8.3.1.17.2, modified from SCP Figures 8.3.1.17-1, 8.3.1.17-4;
for Investigation 8.3.1.17.3, modified from SCP Figures 8.3.1.17-1 and 8.3.1.17-5.

Figure 4-2. Information required from Study 8.3.1.17.4.12 for issue resolution through studies in preclosure tectonics program.



Sources of information:

for investigation 8.3.1.8.1, modified from SCP Figure 8.3.1.8-3
for investigation 8.3.1.8.2, modified from SCP Figures 8.3.1.8-1, and Figure 8.3.1.8-4;
for investigation 8.3.1.8.3, modified from SCP Figure 8.3.1.8-1, 8.3.1.8-5, 8.3.1.8-6, and 8.3.1.8-7;
for investigation 8.3.1.8.4, modified from SCP Figures 8.3.1.8-1 and Figure 8.3.1.8-8;
for investigation 8.3.1.6.3, modified from SCP Figures 8.3.1.6-1

Figure 4-3. Information required from Study 8.3.1.17.4.12 for issue resolution through studies in the erosion and postclosure tectonics programs.

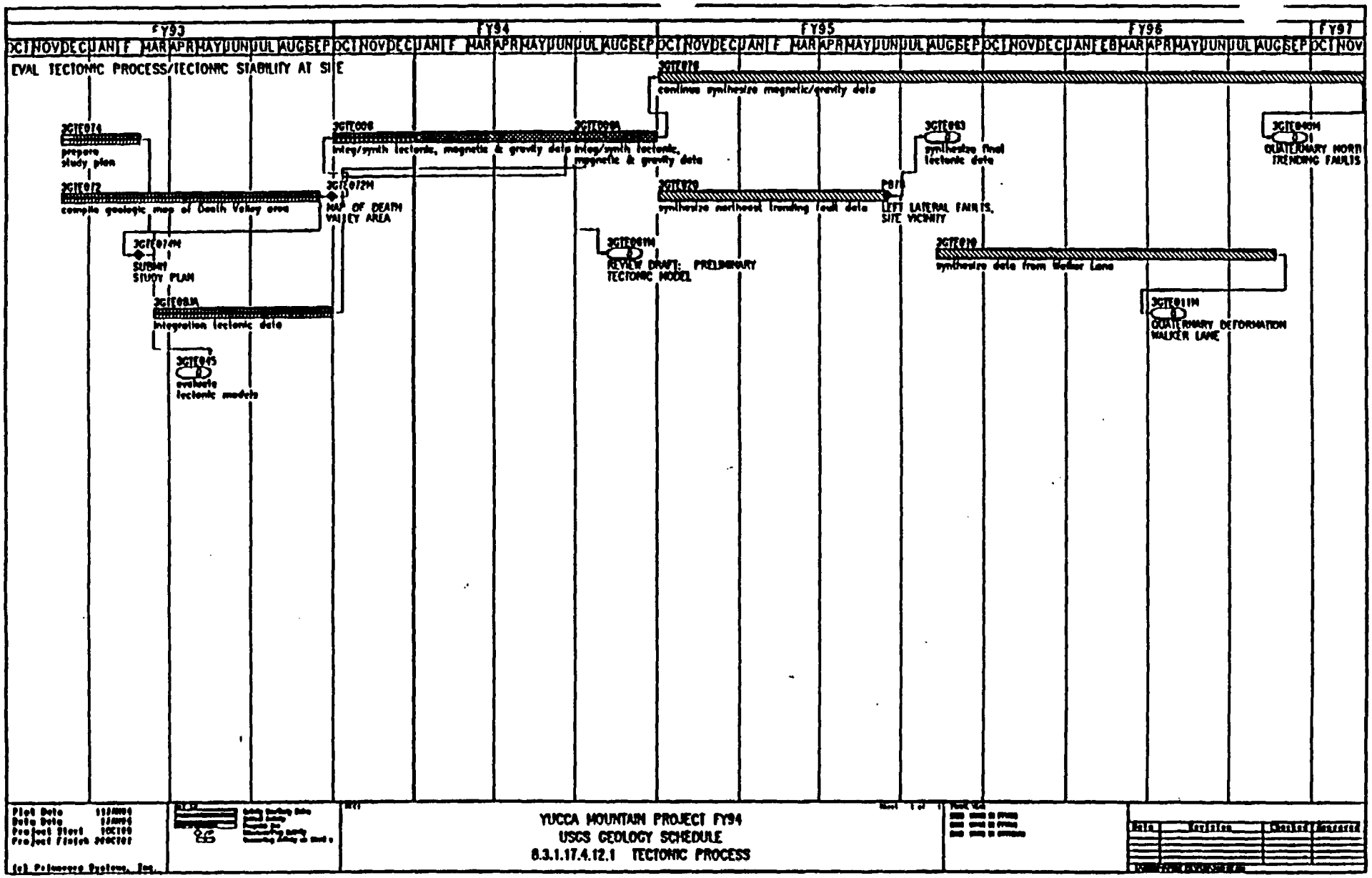


Figure 5-1a. Schedule and milestones (numbers followed by "M") for Activity 8.3.1.17.4.12.1.

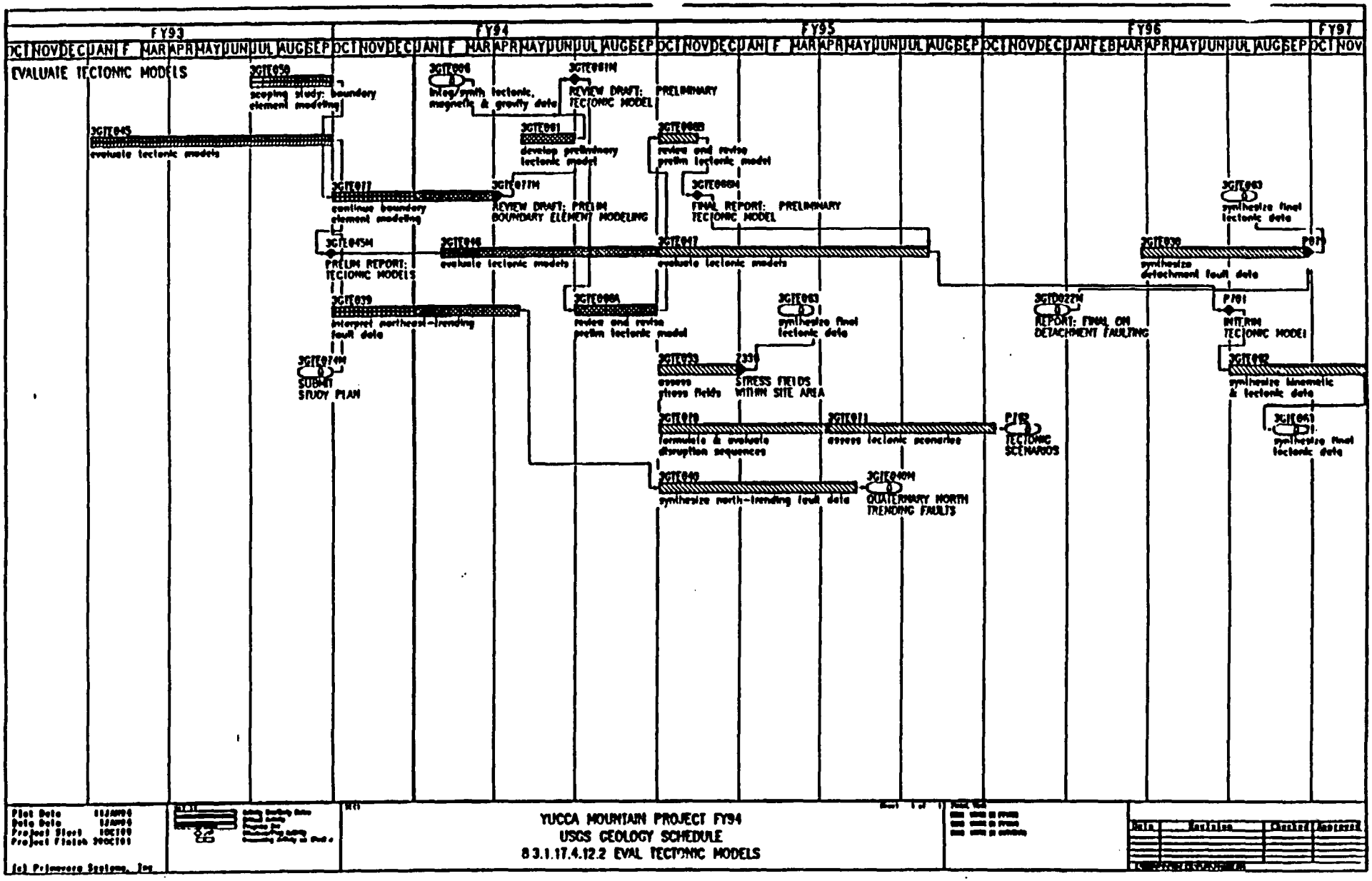


Figure 5-1b. Schedule and milestones (numbers followed by "M") for Activity 8.3.1.17.4.12.2.

Table 4-1. Information to be provided to other studies by Study 8.3.1.17.4.12

Information to be obtained	Where information will be used[1]	How information will be used
Tectonic interrelationships among local faults.	8.3.1.17.2.1.1	To assess the stability of the site surface with respect to fault displacement, at locations proposed for surface facilities important to safety
	8.3.1.17.2.1.2	To assess potential for displacement on faults that intersect underground facilities
Data on the style and rate of Quaternary faulting in the site region. Maps showing Quaternary faults with lengths greater than 20 km within 100 km of the site.	8.3.1.17.3.1.1	To identify and characterize those earthquake sources that are relevant to a deterministic seismic hazard analysis of the site (i.e., those sources that could be active) and, if active, could generate severe ground shaking at the site.
Data on neotectonic deformation or stability in the site region. Regional heat-flow anomaly maps and regional and local magnetic-anomaly and gravity anomaly maps. Regional and local crustal seismic data. Information on local and regional crustal stresses.	8.3.1.17.3.5*	To identify controlling seismic events and to characterize the resulting controlling ground motion (i.e., those UNEs or 10,000-year cumulative slip earthquakes that would generate the most severe ground motions at the site, at frequencies of engineering significance).

Table 4-1. Information to be provided to other studies by Study 8.3.1.17.4.12 (cont.)

Information to be obtained	Where information will be used[1]	How information will be used
Local and regional tectonic models - Model(s) that relate the nature and estimated rates (including bounding values of those estimated rates) of Quaternary processes (volcanism, faulting, uplift and subsidence, lateral strain, and folding) of potential significance to design and performance of the repository at Yucca Mountain.	8.3.1.17.3.6	To quantify the probability for experiencing ground motions of varying degrees of severity that might result from earthquakes of varying magnitude and distance from the site.
Fault map of region that differentiates Quaternary faults from older faults. Late Tertiary tectonic map of region. Regional aeromagnetic, gravity, and seismic data in the site region. Tectonic model(s) that relate the nature and estimated rates (including bounding values of those estimated rates) of Quaternary processes (volcanism, faulting, uplift and subsidence, lateral strain, and folding) of potential significance to design and performance of the repository at Yucca Mountain.	8.3.1.8.1.1.2	To evaluate structural controls of basaltic volcanic activity.
Evaluation of tectonic models with respect to Quaternary volcanism. Two models under consideration include: (1) association with an incipient rift zone (Death Valley-Pancake Range zone), and (2) a leaky transform model.	8.3.1.8.1.1.3 8.3.1.8.5	To determine whether there are any indications of the presence of magma bodies or indications of the operation of magmatic processes in the crust beneath the Yucca Mountain area.

Table 4-1. Information to be provided to other studies by Study 8.3.1.17.4.12 (cont.)

Information to be obtained	Where information will be used[1]	How information will be used
Regional and local magnetic-anomaly and gravity anomaly maps. Regional and local crustal seismic data.		To ensure that sufficient site characterization data are being obtained to adequately investigate the presence of magma bodies in the Yucca Mountain vicinity.
Tectonic model synthesis, including the probability and expected magnitude of faulting in the Yucca Mountain area during the repository postclosure period.	8.3.1.6.	To evaluate the effects of future tectonic activity on erosion at Yucca Mountain.
Synthesis of data relevant to faulting, magmatic activity, folding, uplift and subsidence; including data on gravity residuals, magmatic residuals, seismic velocities, in situ stress, geologic structure and stratigraphy, and tectonic geomorphology. Geologic maps and cross sections of Yucca Mountain and vicinity depicting location and extent of faults, as well as the amount and timing of displacement of Quaternary datums.	8.3.1.8.2.1	To assess the likelihood of waste package rupture due to tectonic processes and events (i.e., rupture due to igneous intrusion, faulting, folding and deformation).
Dilation of faults and fractures as a consequence of fault slip.	8.3.1.8.3.1	To assess the effects of tectonic processes and events on average percolation flux rates over the repository.
Orientation of possible intrusions. Strain rates in area, amount of episodic change in strain due to faulting events.	8.3.1.8.3.2	To analyze the effects of tectonic processes and events on changes in water-table elevation.

Table 4-1. Information to be provided to other studies by Study 8.3.1.17.4.12 (cont.)

Information to be obtained	Where information will be used[1]	How information will be used
Strain rates in area, amount of eposidic change in strain due to faulting events. Dilation of faults and fractures as a consequence of fault slip.	8.3.1.8.3.3	To analyze the effects of tectonic processes and events on local fracture permeability and effective porosity.
Local and regional tectonic models - Models that relate the nature and estimated rates (including bounding values of those estimated rates) of Quaternary processes (volcanism, faulting, uplift and subsidence, lateral strain, and folding) of potential significance to design and performance of the repository at Yucca Mountain.	8.3.1.8.4.1*	To analyze the effects of tectonic processes and events on rock geochemical properties.
	8.3.1.2.1.4.1*	To be assimilated with information from other studies into a description of the regional hydrologic flow system.
	8.3.1.4.2.3*, 8.3.1.4.3.2*	To be integrated with information from other studies to formulate the site geologic model(s) and three-dimensional rock characteristics models.
Regional and local magnetic anomaly and gravity anomaly maps.	8.3.1.9.2.1.2*	To review geophysical data and models in light of natural resource assessment.
Local and regional tectonic models.		To assess tectonic models relative to their significance to ore-forming processing. To provide a geophysical/geologic basis for analog environments.

Table 4-1. Information to be provided to other studies by Study 8.3.1.17.4.12 (cont.)

---

[1]Studies or activities in which information will be used:

8.3.1.2.1.4.1: Conceptualization of regional hydrologic flow models.

8.3.1.4.2.3: Three-dimensional geologic model.

8.3.1.4.3.2: Three-dimensional rock characteristics models.

8.3.1.6.: Erosion program - Description of the future erosional rates required by the performance and design issues.

8.3.1.8.1.1.2: Evaluation of structural controls of basaltic volcanic activity.

8.3.1.8.1.1.3: Presence of magma bodies in the vicinity of the site.

8.3.1.8.2.1: Analysis of waste package rupture due to tectonic processes and events.

8.3.1.8.3.1: Analysis of the effects of tectonic processes and events on average percolation flux rates over the repository.

8.3.1.8.3.2: Analysis of the effects of tectonic processes and events on changes in water-table elevation.

8.3.1.8.3.3: Analysis of the effects of tectonic processes and events on local fracture permeability and effective porosity.

8.3.1.8.4.1: Analysis of the effects of tectonic processes and events on rock geochemical properties.

8.3.1.8.5: Studies to provide the information required by the analysis and assessment investigations of the tectonics program.

8.3.1.9.2.1.2: Geophysical/geologic appraisal of the site relative to mineral resources.

8.3.1.17.2.1: Faulting potential at the repository.

8.3.1.17.3.1.1: Identify relevant earthquake sources.

8.3.1.17.3.5: Ground motion at the site from controlling seismic events.

8.3.1.17.3.6: Probabilistic seismic hazards analyses.

*Information from Study 8.3.1.17.4.10 will be used indirectly in this study/activity.

TABLE 2-1

PRELIMINARY LIST OF ALTERNATIVE TECTONIC MODELS
DRAFT

MODEL: Walker Lane (Regional)

Boundaries - Sierra Nevada block on the west and north-northeast trending mountain ranges on the east.

Boundary Conditions - Regional right lateral shear couple.

Fault Geometries - Vertical faults in Death Valley, Fish Lake Valley, Owen's Valley and the Central Walker Lane. Low angle faults between Fish Lake Valley and the Central Walker Lane, and perhaps other transfer zones.

Fault Kinematics - Right lateral strike-slip and normal/oblique slip. Overall compatible with the displacement vector for the Sierra Nevada block with respect to North America.

Geometric/Lithologic Characteristics - Volcanic fields related to step-overs within the strike-slip fault system. Basin geometries related to the strike-slip fault geometries.

MODEL: Extensional (Regional)

Boundaries - Sheep Range, Spring Mountains, Death Valley and the Timber Mountain Caldera (?). One or more basal detachment faults.

Boundary Conditions - Extension at the Sheep Range and Death Valley. Shear strain at other boundaries.

Fault Geometries - Steep normal faults within the region and at the extensional boundaries. Subhorizontal detachment faults at the base. Some faults may be at intermediate angles because of rotation.

Fault Kinematics - Strike-slip and normal displacements to accommodate extension at N 50-70 W.

Geometric/Lithologic Characteristics - Volcanic Fields related to domain boundaries. Basin geometries related to rotated fault blocks.

MODEL: Pull-Apart Basin

Boundaries - Yucca Wash/Northern Crater Flat, Bare Mountain, Forty-Mile Wash, Pahrump-Stewart Valley Fault zone or, perhaps, the northeast boundary of the Amargosa Valley.

Boundary Conditions - Right-lateral shear on the northern and southern boundary faults. Extensional strain and the eastern and western boundary faults. May have a basal detachment fault.

Fault Geometries - Vertical strike-slip faults north and south. High angle basin bounding faults east and west. High angle normal faults within the basin, and may have low-angle detachment fault.

Fault Kinematics - Extension and basin formation result from strike-slip motion on northern and southern boundaries.

Geometric/Lithologic Characteristics - Crater Flat volcanic field, some workers would expand the size of the basin to include volcanics of the Greenwater and the Pancake volcanic fields. Geometry of the Tertiary sedimentary basin fill, as defined by gravity data.

MODEL: Strike-Slip Couple

Boundaries - Yucca Wash/Northern margin of Crater Flat and northeastern margin of the Amargosa Valley.

Boundary Conditions - Right-lateral shear couple on northern and southern boundary. Eastern and western boundaries rotate, but do not necessarily experience extension.

Fault Geometries - Vertical faults at northern and southern boundaries, steep fault between.

Fault Kinematics - Right-lateral strike-slip on northern and southern boundaries, left-oblique on high angle faults.

Geometric/Lithologic Characteristics - Small scale structures consistent with the overall right-lateral shear couple.

MODEL: Buried Strike-Slip Fault

Boundaries - Defined by the distribution of Tertiary volcanic rocks.

Boundary Conditions - Right-lateral displacement on fault that cuts the pre-Tertiary basement rocks, but not the Tertiary volcanics. Shear stress on the base of the volcanics. Zero displacement at the edge of the volcanics.

Fault Geometries - Vertical or near vertical fault in the basement. Detachment fault at the basal contact of the Tertiary volcanic rocks. Steeply dipping faults within the volcanic section.

Fault Kinematics - Basement behaves as two rigid blocks displaced in right-lateral sense. Faults in volcanics form and move in response to right-lateral shear couple.

Geometric/Lithologic Characteristics - Fault and fracture patterns in the volcanics consistent with right-lateral shear, similar to clay block experiments.

MODEL: Caldera

Boundaries - Margins of the Crater Flat caldera defined by Carr.

Boundary Conditions - Downdropping and extension along the margins of the caldera.

Fault Geometries - High angle, dipping into the caldera on all sides.

Fault Kinematics - Normal slip associated with caldera collapse.

Geometric/Lithologic Characteristics - Volcaniclastic and sedimentary deposits associated with caldera formation and infilling. Structures associated with collapse.

MODEL: "Rooted" Normal Faults

Boundaries - Sheep Range, Spring Mountains, Funeral Mountains, Timber Mountain Caldera.

Boundary Conditions - Extension at Sheep Range and Funeral Mountains, shear strain at other boundaries.

Fault Geometries - Steeply dipping faults that cut through the entire brittle crust.

Fault Kinematics - Normal slip on steep faults, may have some strike-slip especially at the boundaries.

Geometric/Lithologic Characteristics - Sedimentary basins related to rotated fault blocks. No systematic relation between volcanics and fault geometries.

APPENDIX

BOUNDARY ELEMENT MODELING CODE

(Program developed by Geoffrey King, University of Strasbourg, France, and submitted to U. S. Geological Survey, April, 1994)

Note: This code has not been reviewed for QA software standards (YMP-USGS-QMP-3.03, R5. It is the code used for a preliminary scoping study to determine whether boundary element modeling can be used as an aid to evaluating tectonic models applied to Yucca Mountain. The results of the scoping study were sufficiently encouraging to proceed with any necessary revisions to meet full QA software standards.

```
*     TEMPLATE - Main program

      PROGRAM Template

*     This file is based on Microsoft Fortran's "demo" program file.  It has
*     been modified by R. W. Allmendinger to incorporate the following things
*     not covered by the demo program:
*
*           • checking menu items
*           • refreshing the screen
*           • using the mouse to get screen coordinates interactively
*           • manipulating pictures
*           • saving a plot or diagram as a "PICT" file
*
*     These things work for me in my programs.  However, I claim no respon-
*     sibility for their accuracy, or effectiveness.
*
*
*     note that the "demo.inc" file has been changed somewhat from that dis-
*     tributed by Microsoft by addition of the following:
*
*           INTEGER SETWINDOWPIC
*           PARAMETER (SETWINDOWPIC=Z'92E12000')
*           INTEGER GETHANDLESIZE
*           PARAMETER (GETHANDLESIZE=Z'02580028')
*           INTEGER HLOCK
*           PARAMETER (HLOCK=Z'02980008')
*           INTEGER HUNLOCK
*           PARAMETER (HUNLOCK=Z'02A80088')
*           INTEGER GETWTITLE
*           PARAMETER (GETWTITLE=Z'91916000')
*           INTEGER CHECKITEM
*           PARAMETER (CHECKITEM=Z'94511600')
*           integer INITPACK
*           parameter (INITPACK=Z'9E508000')
*
*     "demo.inc" has also been modified to delete all Quickdraw calls which
*     are included in "quickdraw.inc"


      include demo.inc
      include quickdraw.inc

*
*  Pointer for creating the menus
*

      integer*4 menuhdl1,menuhdl2,menuhdl3,menuhdl4    ! pointers to menu
      integer*4 menuhdl5,menuhdl6


      integer*4 eventmask            ! specifies the events of interest

      integer*2 eventrecord(8)       ! overlying structure

      integer*2 what                 ! type of event:
```

```
c       0 = null          1 = mouse down    2 = mouse up        3 = key down
c       4 = key up        5 = auto-key      6 = update        7 = disk inserted
c       8 = activate      9 = abort        10 = network      11 = I/O driver
c      12 = application defined            13 = application defined
c     14 = application defined             15 = application defined

      integer*4 message        ! extra event information:

      integer*4 when                  ! time of event in 60ths of seconds
      integer*2 where(2)              ! mouse location in global coordinates
      integer*2 modifiers             ! state of mouse button and modifier keys:

      equivalence (eventrecord(1),what)
      equivalence (eventrecord(2),message)
      equivalence (eventrecord(4),when)
      equivalence (eventrecord(6),where(1))
      equivalence (eventrecord(8),modifiers)


*
*  The following structure defines a window record for making calls to the
*  Macintosh window manager. The two windows defined by this program will
*  not need to manipulate the window record, but the structure is defined
*  for your reference
*

      integer*4 data_window           ! pointer to the tty window
      integer*4 plot_window           ! pointer to the graphics window

      integer*1 tty_record(154)       ! tty window record
      integer*1 circle_record(154)    ! graphics window record

      integer*2 port(53)              ! grafport
      integer*2 windowkind            ! type of window:
c                               !   0 = standard document window
c                               !   1 = alert box or modal dialog box
c                               !   2 = plain box
c                               !   3 = plain box with shadow
c                               !   4 = document window without size box
c                               !  10 = round cornered window
      logical*1 visible         ! true when window is visible
      logical*1 hilite          ! highlighted when true
      logical*1 goaway          ! has a go away box when true
      logical*1 spareflag       ! reserved
      integer*4 strucrgn        ! Quickdraw region
      integer*4 contrgn         ! Quickdraw region
      integer*4 updatergn       ! Quickdraw region
      integer*4 windowdefproc   ! pointer to window definition function
      integer*4 datahandle      ! pointer for window definition function
      integer*4 titlehandle     ! pointer to title
      integer*4 titlewidth      ! width (in pixels) of title
      integer*4 controllist     ! pointer to control list for Control Mgr
      integer*4 nextwindow      ! pointer to next window in window list
      integer*4 windowpic       ! pointer to Quickdraw picture of contents
      integer*4 refcon          ! reference value field

      equivalence (tty record(1),port)
```

```
      equivalence (tty_record(104),windowkind)
      equivalence (tty_record(109),visible)
      equivalence (tty_record(110),hilite)
      equivalence (tty_record(111),goaway)
      equivalence (tty_record(112),spareflag)
      equivalence (tty_record(113),strucrgn)
      equivalence (tty_record(114),contrgn)
      equivalence (tty_record(121),updatergn)
      equivalence (tty_record(125),windowdefproc)
      equivalence (tty_record(129),datahandle)
      equivalence (tty_record(133),titlehandle)
      equivalence (tty_record(137),titlewidth)
      equivalence (tty_record(139),controllist)
      equivalence (tty_record(143),nextwindow)
      equivalence (tty_record(147),windowpic)
      equivalence (tty_record(151),refcon)


*
*  Miscellaneous declarations
*

      integer*4 toolbx          ! the tool box interface
      character*256 str255      ! function to create a Pascal LSTRING
      integer*4 window          ! general purpose pointer
      integer*4 size,w,ht       ! for growing windows
      integer*2 rect(4)         ! rectangle coordinates
      integer mouseloc          ! mouse location from FINDWINDOW:
c                               !   0 = none of the following
c                               !   1 = in the menu bar
c                               !   2 = in system window
c                               !   3 = in content region
c                               !   4 = in drag region
c                               !   5 = in grow region
c                               !   6 = in go away region

c     common  !  whatever common statements you may have

      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
      REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
      INTEGER*4 NUM
      COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
     1,BVS(500),BVN(500),DPA(500),NUM(500)
      INTEGER*4 KODES
      COMMON/S7/KODES(500)
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      REAL*4 XM,YM,A,COSBET,SINBET
      INTEGER*4 KOD
      COMMON/S9/XM(500),YM(500),A(500),COSBET(500)
```

```
     1,SINBET(500),KOD(500)
      REAL*4 C,B,D,DIPA
      COMMON/S10/C(1000,1000),B(1000),D(1000),DIPA(1000)
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      INTEGER*4 picthdl
      COMMON/S12/picthdl(2)
      REAL*4 STARTX2,STARTX3,FINX2,FINX3,DELX2,DELX3,STMAX1
     +,DELT,FRIC,SIZ,FLUID,EXAGG,FAULT
      INTEGER*4 IGRID
      COMMON/S13/STARTX2,STARTX3,FINX2,FINX3,DELX2,DELX3,STMAX1
     +,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT
      LOGICAL*4    Screen,Matrix,Displacements,StressStrain
      COMMON/S14/ Screen,Matrix,Displacements,StressStrain
      INTEGER*4  NUMB1,NUMB2
      COMMON/S16/ NUMB1,NUMB2
      REAL*4       offsetx,offsety,scalex,scaley
      LOGICAL*4    in_grid
      COMMON/S17/ offsetx,offsety,scalex,scaley,in_grid
      COMMON/S18/ menuhdl3,menuhdl4

      CHARACTER*150 Header1, Header2
      CHARACTER*30 Line_end
      COMMON/S19/ Header1,Header2,Line_end(500)

      INTEGER*4 width,height                 ! for growing windows
      INTEGER*2 scrrect
      COMMON/S20/ scrrect(4),width,height

      LOGICAL*4 button1
      INTEGER*2 textrect(4),mousepos(2)

      Header1 = '  '
      Header2 = '  '
      Line_end(1) = '  '

      scrrect(1) = 0                              !  Top
      scrrect(2) = 0                              ! Left
      scrrect(3) = 1500                           ! Bottom
      scrrect(4) = 1500                           ! Right


      OPEN(4,ACCESS="SEQUENTIAL",STATUS="UNKNOWN",FILE="example")

*
*  Set up the event manager mask (you should accept responsibility for all
*  events to insure that the event queue is flushed: some calls such as
*  MENUSELECT will not work properly if there are extra mouse-up events
*  lying around):
*
      eventmask = -1

*
*  Close MacFortran I/O window (never make a DISPOSEWINDOW call on this
*  window):
```

```
*

      window = toolbx(FRONTWINDOW)
      call toolbx(CLOSEWINDOW,window)

*
*  Build the menus (for details refer to "Menu Initialization and
*  Allocation" in "The MacFortran Tool Box Interface"):
*

      menuhdl1 = toolbx(NEWMENU,30,str255("File"))
      call toolbx(APPENDMENU,menuhdl1,
     +                 str255("New;Old;-(;
     +Save Plot;Save Text;-(;Transfer;Quit"))
      call toolbx(INSERTMENU,menuhdl1,0)          ! insert at end of list

*     (a menu has been deleted here for this template file)

      menuhdl3 = toolbx(NEWMENU,32,str255("Calculations"))
      call toolbx(APPENDMENU,menuhdl3,
     +            str255("Calculate"))
      call toolbx(INSERTMENU,menuhdl3,0)          ! insert at end of list

      menuhdl4 = toolbx(NEWMENU,33,str255("Plot"))
      call toolbx(APPENDMENU,menuhdl4,
     +            str255("Plot to Save;Screen Plot"))
      call toolbx(INSERTMENU,menuhdl4,0)          ! insert at end of list

      menuhdl5 = toolbx(NEWMENU,34,str255("Options"))
      call toolbx(APPENDMENU,menuhdl5,
     +                  str255("View old file;Output matrix & elements;O
     +utput displacement;Output StressStrain;-(;Output for given points;
     +-("))
      call toolbx(INSERTMENU,menuhdl5,0)          ! insert at end of list

      menuhdl6 = toolbx(NEWMENU,35,str255("Windows"))
      call toolbx(APPENDMENU,menuhdl6,
     +                 str255("Data Entry;Plot"))
      call toolbx(INSERTMENU,menuhdl6,0)          ! insert at end of list


      call toolbx(DISABLEITEM,menuhdl3,0)
      call toolbx(DISABLEITEM,menuhdl4,0)
      call toolbx(DISABLEITEM,menuhdl5,6)


      call toolbx(DRAWMENUBAR)

C    disable mouse get position routine until grid is run

                 in_grid = .false.

C     check the default choices in the "Options" menu

                 Screen = .false.
                 Matrix = .false.
                 Displacements = .false.
```

```
                StressStrain = .false.

      call toolbx(CHECKITEM,menuhdl5,1,Screen)      !  check Screen O/P
      call toolbx(CHECKITEM,menuhdl5,2,Matrix)      !  check Matrix O/P
      call toolbx(CHECKITEM,menuhdl5,3,displacements) !  check Disp O/P
      call toolbx(CHECKITEM,menuhdl5,4,StressStrain)  !  check Stress/Strain

*
*  Create the windows, only display the plot window; the SETPORT call
*  allows FORTRAN I/O to take place:
*

      data_window = toolbx(PTR,tty_record) ! This is the initial size of the port
      rect(1) = 40                         !  Top
      rect(2) = 0                          !  Left
      rect(3) = 380                        ! was 342 Bottom
      rect(4) = 620                        ! was 512 Right
      data_window = toolbx(NEWWINDOW,data_window,rect,
     +                 str255("Data Entry"),.true.,0,-1,.true.,0)

      call toolbx(SETPORT,data_window)     !  set the default text style
      call toolbx(TEXTFONT,4)        ! monaco
      call toolbx(TEXTSIZE,9)        ! 9 point


      rect(1) =  40  ! was 25
      rect(2) =  0  ! was 25
      rect(3) = 380 !was 342
      rect(4) = 620 !was 512
      width   = 620
      height  = (380-40)

      plot_window = toolbx(PTR,circle_record)

      plot_window = toolbx(NEWWINDOW,plot_window,rect,
     +                 str255("Plot"),.true.,0,-1,.true.,0)
      call toolbx(SETPORT,plot_window)     !  go to the new Plot_window
      call toolbx(BRINGTOFRONT,plot_window)
      call toolbx(CLIPRECT,scrrect)
      picthdl(1) = toolbx(OPENPICTURE,scrrect)  ! make a title picture for

      call toolbx(TEXTFONT,0)        ! Chicago
      call toolbx(TEXTSIZE,12)       ! 12 point

      call toolbx(MOVETO,145,40)
      write(9,*) '     Deformation  Program'
      call toolbx(TEXTFACE,0)
      write(9,*)
      call toolbx(MOVE,145,0)
      write(9,*) '                    by'
      write(9,*)
      call toolbx(MOVE,145,0)
      write(9,*) '            Geoffrey  King'
      call toolbx(MOVE,145,0)
      write(9,*) '     '
      call toolbx(MOVE,145,0)
```

```
      write(9,*) 'Institut de Physique du Globe'
      call toolbx(MOVE,145,0)
      write(9,*) '       5, rue Réne Descartes,'
      call toolbx(MOVE,145,0)
      write(9,*) '            67084 Strasbourg '
      call toolbx(MOVE,145,0)
      write(9,*) '                  FRANCE '
      write(9,*)
      call toolbx(MOVE,140,0)
      WRITE(9,*) '  This program is not to be sold.'
      call toolbx(MOVE,122,0)
      WRITE(9,*) 'Reference by name and address above.'
      call toolbx(MOVE,74,0)
      WRITE(9,*) '(Commercial users note copywrite on part of the
     1 code)'
      call toolbx(MOVE,80,20)
      WRITE(9,*) '  To start, select "New" or "Old"
     &from the File Menu'
      call toolbx(TEXTFONT,4)        ! monaco
      call toolbx(TEXTSIZE,9)        ! 9 point
      call toolbx(CLOSEPICTURE)
      call toolbx(DRAWPICTURE,picthdl(1),scrrect)
      call toolbx(SETWINDOWPIC,plot_window,picthdl(1))       ! to have the screen
refreshed
      call toolbx(SHOWWINDOW,plot_window)


*
*  main event processing loop
*
*  constraints on window dragging:
*
                  Itimes=0

        do
          if (toolbx(GETNEXTEVENT,eventmask,eventrecord)) then

            select case (what)

              case (1)         ! mouse down

              mouseloc = toolbx(FINDWINDOW,where,window)

                if (mouseloc=1) then
                  call menus(where,data_window,plot_window,menuhdl5)

C     the following routine allows you to use the mouse at any time to get
C     the coordinates in the plot window.  The coordinates are displayed as
C     long as the mouse button is held down

                else if (mouseloc=3) then
                  call toolbx(SELECTWINDOW,window)
                  if(window=plot_window) then
                  if(in_grid) then
                  call toolbx(SETPORT,plot_window)
                  call toolbx(GETMOUSE,mousepos)
                  IXX = mousepos(2)
```

```
                IYY = mousepos(1)

                ! statements to convert the X,Y coords of the mouse to
                ! coordinates of your plot.  Should include write state-
                ! ments to display the coordinates

                if(Itimes.EQ.2)then
                call Makels(plot_window,data_window
     +         ,IX,IY,IXX,IYY,Itimes)
                else
                Itimes=2
                endif
                IX=IXX
                IY=IYY
                endif
                  do        ! delay the update stmts until mouse is released
                    buttonl = toolbx(BUTTON)
                    if (buttonl = .false.) exit
                  repeat

C     statements below refresh the screen only where the text was initially
C     written

                  call toolbx(ERASERECT,textrect)
                  call toolbx(INVALRECT,textrect)
                  call toolbx(BEGINUPDATE,plot_window)
                  call toolbx(DRAWPICTURE,picthdl(1),scrrect)
                  call toolbx(ENDUPDATE,plot_window)
                  call toolbx(SETPORT,data_window)
                  endif

              else if (mouseloc=4) then
                call toolbx(DRAGWINDOW,window,where,scrrect)
              else if (mouseloc=5) then
                size = toolbx(GROWWINDOW,window,where,scrrect)
                w = size .and. z'ffff'
                ht = shift(size,-16)
                call toolbx(SIZEWINDOW,window,w,ht,.true.)
                width  = w
                height = ht
              else if (mouseloc=6) then
                if (toolbx(TRACKGOAWAY,window,where))
     +                    call toolbx(HIDEWINDOW,window)
              end if

            case default

          end select

        end if
      repeat
      CLOSE(4)
      end


*
* menus: a mouse down event was detected in the menu area; process menu
```

```
*       selection
*

      SUBROUTINE MENUS(where,data_window,plot_window,menuhdl5)

C     note that menuhdl5 must be passed along so that we can change the
C     checks in the menu when the defaults are changed

      include demo.inc
      include quickdraw.inc

c     common   !  whatever common statements you may have

      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
      REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
      INTEGER*4 NUM
      COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
     1,BVS(500),BVN(500),DPA(500),NUM(500)
      INTEGER*4 KODES
      COMMON/S7/KODES(500)
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      REAL*4 XM,YM,A,COSBET,SINBET
      INTEGER*4 KOD
      COMMON/S9/XM(500),YM(500),A(500),COSBET(500)
     1,SINBET(500),KOD(500)
      REAL*4 C,B,D,DIPA
      COMMON/S10/C(1000,1000),B(1000),D(1000),DIPA(1000)
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      INTEGER*4 picthdl
      COMMON/S12/picthdl(2)
      REAL*4 STARTX2,STARTX3,FINX2,FINX3,DELX2,DELX3,STMAX1
     +,DELT,FRIC,SIZ,FLUID,EXAGG,FAULT
      INTEGER*4 IGRID
      COMMON/S13/STARTX2,STARTX3,FINX2,FINX3,DELX2,DELX3,STMAX1
     +,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT
      LOGICAL*4    Screen,Matrix,Displacements,StressStrain
      COMMON/S14/ Screen,Matrix,Displacements,StressStrain
      INTEGER*4  NUMB1,NUMB2
      COMMON/S16/ NUMB1,NUMB2
      REAL*4       offsetx,offsety,scalex,scaley
      LOGICAL*4    in_grid
      COMMON/S17/ offsetx,offsety,scalex,scaley,in_grid
      COMMON/S18/ menuhdl3,menuhdl4

      character*64 fill, fil2
      integer*4 toolbx
      integer*4 picsize, pictptr
```

```
      integer*2 where(2)              ! mouse location from the event record
      integer*4 data_window           ! tty window pointer
      integer*4 plot_window           ! circle window pointer
      integer window
      integer*2 scrrect(4)
*
*  variables for making menu selections
*
      integer*2 menuselection(2)      ! menu selection information
c                                 !  (1) = menuid
c                                 !  (2) = menu item number
      integer*4 menudata              ! for use left of equals sign

      equivalence (menuselection,menudata)

*
*  Menu selection constants:
*

      integer File,Modify,Calculations,Plot,Windows    ! menus
      integer New,Old,Add_to                        ! "File" menu selections
      integer Print,Chain,Quit,NameFile             ! "Data" menu selections
      integer SavePlot, SaveText
      integer Plot_all,Plot_part,Options, PoreP
      integer Data_Entry,Plots,StRate,PlastConst
      integer Automatic,ChScale, Heat
      integer NewPlot, OldPlot
      integer Calculate

      parameter (File=30,Modify=31,Calculations=32,Plot=33,Options=34,
     &           Windows=35)
      parameter (New=1,Old=2,SavePlot=4,SaveText=5,Chain=7,Quit=8)
      parameter (Calculate=1)
      parameter (NewPlot=1, OldPlot=2)
      parameter (Data_Entry=1, Plots=2)


      DATA scrrect /0,0,480,640/


*
*  The MENUSELECT tool box call handles the messy details of highlighting
*  menus and menu selections, pulling menus down, and determining which
*  item was selected. The HILITEMENU call at the end of the select case
*  blocks actually unhighlights the menus.
*

      menudata = toolbx(MENUSELECT,where)

        select case (menuselection(1))

          case (File)          ! the "File" menu was selected
              select case (menuselection(2))
              case (New)
                call toolbx(SELECTWINDOW,data window)
```

```
          call toolbx(SETPORT,data_window)
          call insing(data_window)
          call toolbx(ENABLEITEM,menuhdl3,0)
          call toolbx(DRAWMENUBAR)
        case (Old)
          call toolbx(SELECTWINDOW,data_window)
          call toolbx(SETPORT,data_window)
          call Old
          call toolbx(ENABLEITEM,menuhdl3,0)
          call toolbx(DRAWMENUBAR)
        case (SavePlot)        !  calls routine to save plot as a PICT file
          call toolbx(SETPORT,plot_window)
          call toolbx(HLOCK,picthdl(1))
          picsize = toolbx(GETHANDLESIZE,picthdl(1))
          pictptr = long(picthdl(1))
          call Save_Plot(pictptr,picsize)
          call toolbx(HUNLOCK,picthdl(1))
          call toolbx(SETPORT,data_window)
        case (SaveText)
          call Save_Text
        case (Chain)           ! to transfer to another application
          call Chain
        case (Quit)
          call toolbx(CLOSEPICTURE)
          call toolbx(KILLPICTURE,picthdl(1))
          stop
      end select
        call toolbx(HILITEMENU,0)

    case (Calculations)        ! the "Operations" menu was selected
        select case (menuselection(2))
        case (Calculate)
        call Calcul(data_window)
        call toolbx(ENABLEITEM,menuhdl4,0)
        call toolbx(ENABLEITEM,menuhdl5,6)
        call toolbx(DRAWMENUBAR)
      end select
      call toolbx(HILITEMENU,0)

    Case (Plot)                ! the "Plot" menu was selected
        select case (menuselection(2))
        case (NewPlot)
          call Grid(data_window,plot_window,NewPlot)
        case (OldPlot)
          call Grid(data_window,plot_window,OldPlot)
      end select
      call toolbx(HILITEMENU,0)

    Case (Options)             ! the "options" menu was selected
        select case (menuselection(2))
          case (1)
            if(Screen)then
            Screen = .false.
            else
            Screen = .true.
            endif
            call toolbx(CHECKITEM,menuhdl5,1,Screen)   !  check
```

```
                case (2)
                  if(Matrix)then
                  Matrix = .false.
                  else
                  Matrix = .true.
                  endif
                  call toolbx(CHECKITEM,menuhdl5,2,Matrix)   !  check
                case (3)
                  if(Displacements)then
                  Displacements = .false.
                  else
                  Displacements = .true.
                  endif
                  call toolbx(CHECKITEM,menuhdl5,3,Displacements) !  check
                case (4)
                  if(StressStrain)then
                  StressStrain = .false.
                  else
                  StressStrain = .true.
                  endif
                  call toolbx(CHECKITEM,menuhdl5,4,StressStrain)   !  check
                case (6)       ! output given points
                  call toolbx(SELECTWINDOW,data_window) ! bring data window to
front
                  call clrtty
                  call GIVEN
              end select
              call toolbx(HILITEMENU,0)

            case (Windows)             ! the "Windows" menu was selected
                select case (menuselection(2))
                case (Data_Entry)
                  window = data_window
                case (Plots)
                  window = plot_window
                end select

              call toolbx(SHOWWINDOW,window)
              call toolbx(SELECTWINDOW,window)
                call toolbx(HILITEMENU,0)

            case default         ! just playing with the mouse

          end select

        return
        end

*
*  chain: transfer control to specified application (the application had
*       better be executable)
*

        subroutine chain


        logical stdfil
```

```
      character*64 filename          ! name of file to execute

      filename = ' '
      call getfil('APPL', filename)
      if (filename = " ") return

      execute trim(filename)

      end

*
*  getfile: prompt user for file name and look it up
*

      subroutine getfil(ftype, filename)

      implicit none

      integer*4 toolbx

      integer*1 reply(76)
      integer*2 good
      character*4 ostype
      integer*2 vrefnum
      integer*2 version
      character*64 fname
      integer flength
      character*64 filename

      equivalence (reply(1), good)
      equivalence (reply(3), ostype)
      equivalence (reply(7), vrefnum)
      equivalence (reply(9), version)
      equivalence (reply(11), fname)

      integer*4 where
      integer*2 wh(2)
      equivalence (wh(1), where)

      logical exist

* File parameter block.  Used to set the default volume in response to a
* Standard File call.
      integer*1 params(80)           ! Enough for all variants.
      integer iolink
      integer*2 iotype
      integer*2 iotrap
      integer iocmdaddr
      integer iocompletion
      integer*2 ioresult
      integer ionameptr
      integer*2 iovrefnum

      equivalence (params(1), iolink)
      equivalence (params(5), iotype)
      equivalence (params(7), iotrap)
```

```
      equivalence (params(9), iocmdaddr)
      equivalence (params(13), iocompletion)
      equivalence (params(17), ioresult)
      equivalence (params(19), ionameptr)
      equivalence (params(23), iovrefnum)

      integer filerr
      INTEGER SFGETFILE
      PARAMETER (SFGETFILE=Z'9EA20003')
      INTEGER PTR, PBSETVOL
      PARAMETER (PTR=Z'C0000000',PBSETVOL=Z'01580010')

      wh(1) = 50
      wh(2) = 50

      call toolbx(SFGETFILE, where, 0, 0, 1,
     +        toolbx(PTR, ftype), 0, reply, 2)

      if (good = 0) then
        filename = ' '
        return
      endif
      flength = ichar(fname(1:1))
      filename = fname(2:flength+1)
      ionameptr = 0
      iovrefnum = vrefnum
      filerr = toolbx(PBSETVOL,
     +        toolbx(PTR, params))
      end


*
*  str255: converts a FORTRAN string to a Pascal LSTRING
*

      character*256 function str255(string)

      character*(*) string

      str255 = char(len(trim(string)))//string

      end



C     ******************************************************************
C
C     SUBROUTINE OLD
C
C     THIS SUBROUTINE ALLOWS ENTRY OF AN OLD DATA SET FROM A DISK FILE.
C
C     ******************************************************************

      SUBROUTINE OLD

c     common    !  whatever common statements your program has
```

```
      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
      REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
      INTEGER*4 NUM
      COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
     1,BVS(500),BVN(500),DPA(500),NUM(500)
      INTEGER*4 KODES
      COMMON/S7/KODES(500)
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      REAL*4 XM,YM,A,COSBET,SINBET
      INTEGER*4 KOD
      COMMON/S9/XM(500),YM(500),A(500),COSBET(500)
     1,SINBET(500),KOD(500)
      REAL*4 C,B,D,DIPA
      COMMON/S10/C(1000,1000),B(1000),D(1000),DIPA(1000)
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      REAL*4 STARTX2,STARTX3,FINX2,FINX3,DELX2,DELX3,STMAX1
     +,DELT,FRIC,SIZ,FLUID,EXAGG,FAULT
      INTEGER*4 IGRID
      COMMON/S13/STARTX2,STARTX3,FINX2,FINX3,DELX2,DELX3,STMAX1
     +,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT
      LOGICAL*4   Screen,Matrix,Displacements,StressStrain
      COMMON/S14/ Screen,Matrix,Displacements,StressStrain
      INTEGER*4  NUMB1,NUMB2
      COMMON/S16/ NUMB1,NUMB2

      CHARACTER*150 Header1
      CHARACTER*150 Header2
      CHARACTER*30 Line_end
      COMMON/S19/ Header1,Header2,Line_end(500)

      INTEGER*4  eof,ios,ret

      logical stdfil
      INTEGER*2 scrrect(4)
      character*64 fill

      DATA scrrect /0,0,480,640/

      call clrtty
      fill = ' '
c     calls up the standard files
      if (stdfil(3,vref,' ',fill,1,'TEXT'))
     +  open (1,file = fill,status = 'old')      ! dialog.  Be sure to have on
      if (fill = ' ') then                       ! same disk or link the
c                                                ! "stdfil.sub" file from the
        return                                   ! subroutines folder
```

```
        endif

      READ(1,220)Header1,Header2
  220 FORMAT(a150,/,a150)

      eof=-1
      ret=0

      READ(1,20,iostat=ios) NUMBS1,NUMBS2,NUMOS,KSYMI,PR1,PR2,ZDEPTH
     1,E1,E2,XSYM,YSYM,PXX,PYY,PXY
      IF(ios.eq.eof)then
      PRINT*,'WARNING  -  Error in GENERAL input parameters'
      return
      ENDIF

      NUMBER=NUMBS1+NUMBS2+NUMOS

      DO 19 N=1,NUMBER
      READ(1,21,iostat=ios)NUM(N),XBEG(N),YBEG(N),XEND(N)
     1,YEND(N),KODES(N),BVS(N),BVN(N),DPA(N),Line_end(N)
   19 CONTINUE

      IF(ios.eq.eof)then
      PRINT*,'WARNING  -  Error in ELEMENT specifiaction'
      PRINT*,'Type 1 to view data, return to reselect'
      READ*,ret
      if(ret.eq.0)return
      Screen=.true.
      ENDIF

   20 FORMAT(6X,I3,8X,I3,10X,I3,6X,I3,/
     +,5X,G15.3,6X,G15.3,6X,G15.3,/
     +,5X,E15.6,6X,E15.6,/
     +,5X,G15.3,6X,G15.3,/
     +,5X,E15.6,6X,E15.6,6X,E15.6,///)


   21  FORMAT(I3,1X,G10.4,1X,G10.4,1X,G10.4,1X,G10.4,1X,I3,1X,G10.4,1X,
     +G10.4,1X,G10.4,a30)

      READ(1,150,iostat=ios) STARTX2,STARTX3,FINX2,FINX3,DELX2
     +              ,DELX3,STMAX1,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT
  150 FORMAT(//,46X,G16.7,/,46X,G16.7,/,46X,G16.7,/,46X,G16.7,/,46X,G16.7
     +,/,46X,G16.7,/,46X,2G16.7,F5.2
     +,/,46X,G16.7,F5.2/,46X,I12,/,46X,G16.7,F5.2)

      IF(ios.eq.eof)then
      PRINT*,'WARNING  -  Error in PLOT parameters.'
      PRINT*,'    A new file must be created'
      PRINT*,'        return to continue'
      ELSE
      OPEN(8,ACCESS="SEQUENTIAL",STATUS="UNKNOWN",FILE="gridout")
      WRITE(8,9100)STARTX2,STARTX3,FINX2,FINX3,DELX2
     +,DELX3,STMAX1,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT
 9100 FORMAT(" 1 ---------------------------  Start-x = ",G16.7
     1    ,/," 2 ---------------------------  Start-y = ",G16.7
     1    ,/," 3 --------------------------   Finish-x = ",G16.7
```

```
1     ,/," 4  --------------------------   Finish-y = ",G16.7
1     ,/," 5  ------------------------- x-increment = ",G16.7
1     ,/," 6  ------------------------- y-increment = ",G16.7
1     ,/," 7  Max strain, shade increment, friction = ",2G16.7,F5.2
1     ,/," 8  Plot size factor,  Skempton's coeff B = ",G16.7,F5.2
1     ,/," 9  ------ Existence of grid and shading = ",I12
1     ,/," 10 Vert Exg,1=Pij used for orientas.only = ",G16.7,F5.2
1     ,/)
 CLOSE(8)
 ENDIF
 close(1)

 IF(KSYMI.NE.5)KSYM=KSYMI
 IHALF=0
 IF(KSYMI.EQ.5)THEN
 KSYM=1
 IHALF=1
 END IF


 IF(Screen)then

 call clrtty
 PRINT*," "
 PRINT*," "
 PRINT*,"       Copyright 1986, Alkane Exploration"
 PRINT*," "
 PRINT*,"   **** REMEMBER THE SIGN CONVENTION *****
 PRINT*," "
 PRINT*,"     Region 1 is always on the left side"
 PRINT*,"            of any element!!!"
 PRINT*," "
 PRINT*,"    * Compressional strains are positive. "
 PRINT*,"    * Element closure is positive "
 PRINT*,"    * Right lateral motion is positive "
 PRINT*," "
 PRINT*,"   Normal refers to opening for 2-D elements "
 PRINT*,"but to dip-slip motion for 3-D half-space elements."
 PRINT*,"          Reverse motion is positive."
 PRINT*,"Dip angle is only read for 3-D half space elements"
 PRINT*,"       and refers to left side of element"
 PRINT*," "
 PRINT*," "
 PRINT*,"          return to continue"

 PAUSE

941 PRINT*," 1-  Number of straight-line segments (each containing at
   1 least one"
 PRINT*,"boundary element ) used to define boundaries of region 1"
 PRINT*,"Region 2 can only have common boundaries with Region 1"
 WRITE (*,6) NUMBS1,NUMBS2
  6 FORMAT(" Boundries of 1 only # =",I3,"   Common with 2 =",I3,/)
 IF(KSYMI.NE.5)KSYM=KSYMI
 IHALF=0
 IF(KSYMI.EQ.5)THEN
 PRINT*," 2 -   **** HALF SPACE SOLUTION **** "
```

```
      KSYM=1
      IHALF=1
      END IF
      GO TO (80,85,90,95),KSYM
   80 WRITE (*,7)
      GO TO 100
   85 WRITE (*,8) XSYM
      GO TO 100
   90 WRITE (*,9) YSYM
      GO TO 100
   95 WRITE (*,10) XSYM,YSYM
    7 FORMAT( 34H 2-No symmetry conditions imposed.)
    8 FORMAT( 20H 2-The line X = XS =,G12.4,23H is a line of symmetry.)
    9 FORMAT( 20H 2-The line Y = YS =,G12.4,23H is a line of symmetry.)
   10 FORMAT( 21H 2-The lines X = XS =,G12.4,13H and Y = YS =,G12.4,
     1 23H are lines of symmetry.)
   12 FORMAT (/,33H 5.xx-component of field stress =,E11.4,//,33H 6.yy-c
     1omponent of field stress =,E11.4,//,33H 7.xy-component of field st
     2ress =,E11.4)

  100 CONTINUE
      WRITE (*,11) PR1,PR2,ZDEPTH,E1,E2
   11 FORMAT(/," 3.- Poisson's ratios. REGION 1 =",F7.2,"     REGION 2
     1=",F7.2,"         DEPTH =",F7.2,//,
     1" 4.- Youngs Modulii.   REGION 1 =",E11.4,"  REGION 2
     1=",E11.4)
      WRITE (*,12) PXX,PYY,PXY
      WRITE (*,666) NUMOS
  666 FORMAT (/," 8-Number of elements with fixed relative slip =",I3)
      PRINT*," "

      PAUSE

      PRINT*,"BOUNDARY ELEMENTS"
      PRINT*," # NUM      XBEG       YBEG       XEND       YEND   KODES
     1    BVS       BVN      DPA"
      DO 973 N=1,NUMBS1
      WRITE(*,921)N,NUM(N),XBEG(N),YBEG(N),XEND(N),YEND(N),KODES(N)
     1,BVS(N),BVN(N),DPA(N)
  921 FORMAT(I2,I3,4X,G10.4,1X,G10.4,1X,G10.4,1X,G10.4,1X,I3,1X,G10.4
     +,1X,G10.4,1X,G10.4)
  973 CONTINUE
      PRINT*,"Shared boundary elements. These KODES must = 7 or 8"
      DO 974 N=NUMBS1+1,NUMBS1+NUMBS2
      WRITE(*,921)N,NUM(N),XBEG(N),YBEG(N),XEND(N),YEND(N),KODES(N)
     1,BVS(N),BVN(N),DPA(N)
  974 CONTINUE
      PRINT*, "SIGN CONVENTION - Displacement values apply to medium to
     1 the LEFT of the"
      PRINT*,"direction in which co-ords are specified. (exc
     lept for KODES= 5)"
      PRINT*,"BVS - shear condition, BVN - normal condition, DPA - ang"
      PRINT*," "
      PRINT*,"KODES= 1- 2 stress conditions,          2- 2 displacement c
     1onditions"
      PRINT*,"       3- 1 displacement & 1 stress,    4- 1 stress & 1 dis
     1placement"
```

```
      PRINT*,"        5- 1 stress condition & 1 relative displacement con
     1dition"
      PRINT*,"        6- 1 relative displacement condition & 1 stress con
     1dition"
      PRINT*,"        7- Shear and Normal stress and displacement continu
     1ous"
      PRINT*,"        8- Normal stress and displacement continuous."
      PRINT*,"           Shear stress is zero and displacement free."
      PRINT*,'        9- Normal spring rate specified in "shear" Normal f
     1ixed'
      PRINT*,'           stress specified in "normal" Shear is free.'
      PRINT*," Values pre-fixed by 1 give crack in full-space where appr
     1opriate."
      PRINT*,"Values pre-fixed by 10 give half-space solutions.  BVN ref
     1ers to the dip-slip "
      PRINT*," component and Dip refers to the dip angle."
      PRINT*,"  "
      PRINT*,"press return to continue."

      PAUSE

      PRINT*,"ELEMENTS WITH FIXED RELATIVE SLIP"
      PRINT*,"  #        XBEG        YBEG        XEND        YEND    KODES
     1Shear slip  Normal slip  Dip angle"
      DO 978 N=NUMBS1+NUMBS2+1,NUMBS1+NUMBS2+NUMOS
      NUM(N)=1
      WRITE(*,923)N,XBEG(N),YBEG(N),XEND(N),YEND(N),KODES(N)
     1,BVS(N),BVN(N),DPA(N)
  923 FORMAT(I3,4X,G10.4,1X,G10.4,1X,G10.4,1X,G10.4,1X,I3,1X,G10.4
     +,1X,G10.4,1X,G10.4)
  978 CONTINUE
      PRINT*,"NOTE- The displacements  are  relative fault  and not"
      PRINT*,"      absolute displacements as for boundary elements."
      PRINT*,"Elements with constant slip are specified with "
      PRINT*,"KODE=0. Use KODE=10 for tapered slip. "
      PRINT*,"KODE=100 for half-space. Normal refers to Dip-slip "
      PRINT*," "

      PAUSE
      endif

      PRINT*,"Now run Calculate"

      return
      end

C     ******************************************************************
C
C     SUBROUTINE Save_Text
C
C     THIS SUBROUTINE ALLOWS one to save text to a DISK FILE.
C
C     ******************************************************************

      SUBROUTINE Save_Text

c     common  !  whatever commons statements you might have
```

```
 REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
1,PYY,PXY
 INTEGER*4 KSYM,IHALF
 COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
1,YSYM,PXX,PYY,PXY,IHALF
 REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
 INTEGER*4 NUM
 COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
1,BVS(500),BVN(500),DPA(500),NUM(500)
 INTEGER*4 KODES
 COMMON/S7/KODES(500)
 INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
1,NUMBE1,NUMBE2,NUMBE3,KSYMI
 COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
1,NUMBE1,NUMBE2,NUMBE3,KSYMI
 REAL*4 XM,YM,A,COSBET,SINBET
 INTEGER*4 KOD
 COMMON/S9/XM(500),YM(500),A(500),COSBET(500)
1,SINBET(500),KOD(500)
 REAL*4 C,B,D,DIPA
 COMMON/S10/C(1000,1000),B(1000),D(1000),DIPA(1000)
 REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
1,UXS,UXN,UYS,UYN
 COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
1,UXS,UXN,UYS,UYN
 INTEGER*4 picthdl
 COMMON/S12/picthdl(2)
 REAL*4 STARTX2,STARTX3,FINX2,FINX3,DELX2,DELX3,STMAX1
+,DELT,FRIC,SIZ,FLUID,EXAGG,FAULT
 INTEGER*4 IGRID
 COMMON/S13/STARTX2,STARTX3,FINX2,FINX3,DELX2,DELX3,STMAX1
+,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT
 LOGICAL*4   Screen,Matrix,Displacements,StressStrain
 COMMON/S14/ Screen,Matrix,Displacements,StressStrain
 INTEGER*4  NUMB1,NUMB2
 COMMON/S16/ NUMB1,NUMB2

 CHARACTER*150 Header1
 CHARACTER*150 Header2
 CHARACTER*30 Line_end
 COMMON/S19/ Header1,Header2,Line_end(500)

 logical stdfil
 INTEGER*2 scrrect(4)
 character*64 fill

 DATA scrrect /0,0,480,640/

 call clrtty
 fill = 'New Data'        ! the word between quotes will be the default name
 if (stdfil(2,vref,'Save data file as?',fill,1,'TEXT'))
+  open (1,file = fill,status = 'UNKNOWN') !to get the standard file dialog
 if (fill = ' ') then                      ! box.
   close(1)
   return
   endif
```

```
      WRITE(1,9907,err=21)Header1,Header2
 9907 FORMAT(a150,/,a150)
      WRITE(1,9901,err=21) NUMBS1,NUMBS2,NUMOS,KSYMI
     1,PR1,PR2,ZDEPTH,E1,E2,XSYM,YSYM,PXX,PYY,PXY
 9901 FORMAT('#reg1=',I3,'  #reg2=',I3,'   #fixed=',I3,'  sym=',I3,/,
     +' PR1=',G15.3,'  PR2=',G15.3,'DEPTH=',G15.3,/,
     +'  E1=',E15.6,'   E2=',E15.6,/,
     +'XSYM=',G15.3,' YSYM=',G15.3,/,
     +' PXX=',E15.6,'  PYY=',E15.6,'  PXY=',E15.6,//,
     +'  #   X-start    Y-start     X-fin      Y-fin   Kode   shear
     +  normal dip angle',/,
     +'xxx xxxxxxxxx xxxxxxxxx xxxxxxxxx xxxxxxxxx xxx xxxxxxxxx x
     +xxxxxxxxx xxxxxxxxx')

      DO 977 N=1,NUMBS1+NUMBS2+NUMOS
      WRITE(1,920,err=21)NUM(N),XBEG(N),YBEG(N),XEND(N),YEND(N)
     1,KODES(N),BVS(N),BVN(N),DPA(N),Line_end(N)

  920 FORMAT(I3,1X,G10.4,1X,G10.4,1X,G10.4,1X,G10.4,1X,I3,1X,G10.4,1X,
     +G10.4,1X,G10.4,a30)

  977 CONTINUE

      WRITE(1,9200,err=21)
 9200 FORMAT(/,'    Grid Parameters')

   99 WRITE(1,9100,err=21)STARTX2,STARTX3,FINX2,FINX3,DELX2
     +            ,DELX3,STMAX1,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT

 9100 FORMAT(" 1  ---------------------------  Start-x = ",G16.7
     1    ,/," 2  ---------------------------  Start-y = ",G16.7
     1    ,/," 3  --------------------------   Finish-x = ",G16.7
     1    ,/," 4  --------------------------   Finish-y = ",G16.7
     1    ,/," 5  ------------------------  x-increment = ",G16.7
     1    ,/," 6  ------------------------  y-increment = ",G16.7
     1    ,/," 7  Max strain, shade increment, friction = ",2G16.7,F5.2
     1    ,/," 8  Plot size factor,  Skempton's coeff B = ",G16.7,F5.2
     1    ,/," 9  ------  Existence of grid and shading = ",I12
     1    ,/," 10 Vert Exg,1=Pij used for orientas.only = ",G16.7,F5.2
     1    ,/)


      close(1)
 21   continue
      return
      end

C     ******************************************************************
C
C     SUBROUTINE SAVE_PLOT
C
C     Routine for saving the diagram in the Plot Window as a PICT file
C     for plotting by MacDraw or other programs
C
C     ******************************************************************
```

```
      SUBROUTINE SAVE_PLOT(pictptr,picsize)

      INCLUDE demo.inc
      include file.inc

      INTEGER*4 picthdl
      COMMON/S12/picthdl(2)

      logical stdfil
      character*2 pictype
      character*4 creator,ftype
      character*256 fil2,string,GetStr,title
      integer*2 error, pichdr(64)
      integer*4 picsize,toolbx,ioreqcount,ionameptr
      integer*4 ios,pictptr,pictbuff,iobuffer
      integer*4 plot_window,data_window,i
      integer*1 params(108)
      integer iocompletion
      integer*2 iovrefnum,vref
      integer*1 ioversnum
      integer*2 iodirindex
      character*4 fdtype, fdcreator
      integer*2 ioposmode
      integer ioposoffset

      equivalence (params(13), iocompletion)
      equivalence (params(19), ionameptr)
      equivalence (params(23), iovrefnum)
      equivalence (params(27), ioversnum)
      equivalence (params(29), iodirindex)
      equivalence (params(33), fdtype)
      equivalence (params(37), fdcreator)
      equivalence (params(33), iobuffer)
      equivalence (params(37), ioreqcount)
      equivalence (params(45), ioposmode)
      equivalence (params(47), ioposoffset)

      ftype = 'PICT'
      creator = 'MSTR'                  ! this goes in header
      fil2 = 'xxxxx.PICT'               ! default name for file to be saved
      pictbuff = picthdl(1)
      if (stdfil(2,vref,'Save plot as?',fil2,0,'    '))
     +   open (6,file=fil2,STATUS='NEW', err = 45)

      iocompletion = 0
      ionameptr = 0
      if (toolbx(PBGETVOL,toolbx(PTR,params)) < 0) goto 46
      vref = iovrefnum
      string = char(len(trim(fil2)))//fil2
      ionameptr = toolbx(PTR,string)
      ioversnum = 0
      iodirindex = 0
      if (toolbx(PBGETFILEINFO,toolbx(PTR,params)) < 0) goto 46
      fdtype = ftype
      fdcreator = creator
      if (toolbx(PBSETFILEINFO,toolbx(PTR,params)) < 0) goto 46
```

```
      do 10 i = 1,64
        pichdr(i) = 0
10    continue
      ioposmode = 1
      ioposoffset = 0
      iobuffer = toolbx(PTR,pichdr)
      ioreqcount = 128
      if (toolbx(PBWRITE,toolbx(PTR,params)) < 0) goto 46
      iobuffer = pictptr
      ioreqcount = picsize
      ioposmode = 1
      ioposoffset = 512
      if (toolbx(PBWRITE,toolbx(PTR,params)) < 0) goto 46
      close(6)
      iocompletion = 0
      ionameptr = 0
      iovrefnum = 0
      error = toolbx(PBFLUSHVOL,toolbx(PTR,params))
      return
45    error = -5000
      return
46    error = -7000
      close(6)
      return
      end
```

```
*       CALCPO

      SUBROUTINE Calcpo(XP,YP,UX,UY,SIGXX,SIGYY,SIGXY,NUMB1,NUMB2)

      IMPLICIT REAL*4(A-H,O-Z)


      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY,DIPANG
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
      REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
      INTEGER*4 NUM
      COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
     1,BVS(500),BVN(500),DPA(500),NUM(500)
      INTEGER*4 KODES
      COMMON/S7/KODES(500)
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      REAL*4 XM,YM,A,COSBET,SINBET
      INTEGER*4 KOD
      COMMON/S9/XM(500),YM(500),A(500),COSBET(500)
     1,SINBET(500),KOD(500)
      REAL*4 C,B,D,DIPA
      COMMON/S10/C(1000,1000),B(1000),D(1000),DIPA(1000)
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN

      UX=0.0
      UY=0.0
      SIGXX=0.0
      SIGYY=0.0
      SIGXY=0.0

      DO 880 J=NUMB1+1,NUMB2
      JN=2*J
      JS=JN-1

      SXXS=0.0
      SXXN=0.0
      SYYS=0.0
      SYYN=0.0
      SXYS=0.0
      SXYN=0.0

      UXS=0.0
      UXN=0.0
      UYS=0.0
      UYN=0.0

      XJ=XM(J)
      YJ=YM(J)
```

```
      AJ=A(J)

      XPA=ABS(XP)
      YPA=ABS(YP)

      COSBJ=COSBET(J)
      SINBJ=SINBET(J)
      DIPANG=DIPA(2*J)

C      PRINT*,XP,YP,XJ,YJ,AJ,COSBJ,SINBJ,+1,KOD(J)

      CALL coeffs(XP,YP,XJ,YJ,AJ,COSBJ,SINBJ,+1,KOD(J),DIPANG)
      GO TO (840,810,820,830),KSYM

  810 XJ=2.0*XSYM-XM(J)
      CALL coeffs(XP,YP,XJ,YJ,AJ,COSBJ,-SINBJ,-1,KOD(J),DIPANG)
      GO TO 840

  820 YJ=2.0*YSYM-YM(J)
      CALL coeffs(XP,YP,XJ,YJ,AJ,-COSBJ,SINBJ,-1,KOD(J),DIPANG)
      GO TO 840

  830 XJ=2.0*XSYM-XM(J)
      CALL coeffs(XP,YP,XJ,YJ,AJ,COSBJ,-SINBJ,-1,KOD(J),DIPANG)
      XJ=XM(J)
      YJ=2.0*YSYM-YM(J)
      CALL coeffs(XP,YP,XJ,YJ,AJ,-COSBJ,SINBJ,-1,KOD(J),DIPANG)
      XJ=2.0*XSYM-XM(J)
      CALL coeffs(XP,YP,XJ,YJ,AJ,-COSBJ,-SINBJ,+1,KOD(J),DIPANG)

  840 CONTINUE

      UX=UX+UXS*D(JS)+UXN*D(JN)
      UY=UY+UYS*D(JS)+UYN*D(JN)
      SIGXX=SIGXX+SXXS*D(JS)+SXXN*D(JN)
      SIGYY=SIGYY+SYYS*D(JS)+SYYN*D(JN)
      SIGXY=SIGXY+SXYS*D(JS)+SXYN*D(JN)

  860 CONTINUE

C      WRITE (*,9920) XP,YP,UX,UY,SIGXX,SIGYY,SIGXY
C 9920 FORMAT (2F12.4,2F12.6,3F12.1)

      RETURN
      END
```

```
*       CALCUL

      subroutine Calcul (tty_window)

*  Notes on indices
*  NUMBS          - does not appear in calcul or, apparently, anywhere
*  NUMBS1         - # unsplit elements in Reg1
*  NUMBS2         - # unsplit elements in Reg2
*  NUMOS          - # unsplit fixed slip elements
*  NUMBE          - floating index to calculate split elements
*  NUMBE1         - # split elements in Reg1 (including shared with Reg2)
*  NUMBE2         - # split elements in Reg2
*  NUMBE3         - # split fixed slip elements
*  NUMB1          -  dummy
*  NUMB2          -  dummy
*  NUM(500)       - array containing subdivision information
*  NED            -  dummy
*  Note other indices in grid

      include demo.inc

      implicit none                        ! helps keep us out of trouble
      integer*4 tty_window                 ! pointer to the tty window

      INTEGER*4 N,NED,IS,JS,JN,NE,M,MN,MS,NN,NS,NUMBE
      INTEGER*4 I,IN,KODE,J,LEAVEOUT


      REAL*4 BV(500),DIPANG
      REAL*4 XI,YI,XJ,YJ,XP,YP,XD,YD
      REAL*4 AAA,SW,ANGLE,SIZE1
      REAL*4 COSB,SINB,COSBI,SINBI,COSBJ,SINBJ
      REAL*4 UX,UY,US,UN,UXNEG,UYNEG,SIGS,SIGN,AJ
      REAL*4 SIGXX,SIGYY,SIGXY
      REAL*4 USNEG,UNNEG,USPOS,UNPOS,UXPOS,UYPOS

      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
      REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
      INTEGER*4 NUM
      COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
     1,BVS(500),BVN(500),DPA(500),NUM(500)
      INTEGER*4 KODES
      COMMON/S7/KODES(500)
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      REAL*4 XM,YM,A,COSBET,SINBET
      INTEGER*4 KOD
      COMMON/S9/XM(500),YM(500),A(500),COSBET(500)
     1,SINBET(500),KOD(500)
      REAL*4 C,B,D,DIPA
      COMMON/S10/C(1000,1000),B(1000),D(1000),DIPA(1000)
```

```
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN

      LOGICAL*4   Screen,Matrix,Displacements,StressStrain
      COMMON/S14/ Screen,Matrix,Displacements,StressStrain
      INTEGER*4  NUMB1,NUMB2
      COMMON/S16/ NUMB1,NUMB2
      character*1 tab
      INTEGER*4  eof,ios

      tab=char(9)

C
      IF(Matrix)then
      OPEN(7,ACCESS="SEQUENTIAL",STATUS="UNKNOWN",FILE="matrix")
      REWIND 7
        write(7,'(a1)') '*'
        write(7,105) tab,tab,tab,tab
 105    format(' Element #',a1,' X2-horiz ',a1,' X3-vert ',a1
     1,' SHEAR ',a1,' NORMAL ',a1,' DIPANG ')
        endif

C     ------------------------------ 2 ---------------------------------
C     Basic constants are calculated
      AAA=1.0
      PI=4.0*ATAN(AAA)
C
C    ------------------------------ 4 ---------------------------------
C
C    Calculates sub-elements. i.e. straight-lines can be broken up
C    to give smaller elements according to values of NUM. This
C    increase of elements requires the creation of a new set of
C    array indices - going from things like NUMBS to things like
C    NUMBE. The program also calculates element mid-points, angles
C    etc. Region 2 elements are specified in the opposite direct-
C    to allow correct boundary condition matching.
C

      NUMBE=0
      DO 110 N=1,NUMBS1+NUMBS2
C
      XD=(XEND(N)-XBEG(N))/NUM(N)
      YD=(YEND(N)-YBEG(N))/NUM(N)
C
      SW=SQRT(XD*XD+YD*YD)
C
      DO 110 NE=1,NUM(N)
      NUMBE=NUMBE+1
      M=NUMBE
      XM(M)=XBEG(N)+0.5*(2.0*NE-1.0)*XD
      YM(M)=YBEG(N)+0.5*(2.0*NE-1.0)*YD
      A(M)=0.5*SW
      SINBET(M)=YD/SW
      COSBET(M)=XD/SW
      KOD(M)=KODES(N)
```

```
      MN=2*M
      MS=MN-1
      B(MS)=BVS(N)
      B(MN)=BVN(N)
      DIPA(MN)=DPA(N)                                   !array for dip angle
  110 CONTINUE
      NUMBE1=NUMBE
C
      DO 111 N=NUMBS1+1,NUMBS1+NUMBS2
C
      XD=(XEND(N)-XBEG(N))/NUM(N)
      YD=(YEND(N)-YBEG(N))/NUM(N)
C
      SW=SQRT(XD*XD+YD*YD)
C
      DO 111 NE=1,NUM(N)
      NUMBE=NUMBE+1
      M=NUMBE
      XM(M)=XBEG(N)+0.5*(2.0*NE-1.0)*XD
      YM(M)=YBEG(N)+0.5*(2.0*NE-1.0)*YD
      A(M)=0.5*SW
C    Note reverse sign of SINBET and COSBET for region 2
      SINBET(M)=-YD/SW
      COSBET(M)=-XD/SW
      KOD(M)=KODES(N)
      MN=2*M
      MS=MN-1
      B(MS)=BVS(N)
      B(MN)=BVN(N)
      DIPA(MN)=DPA(N)                                   !array for dip angle
  111 CONTINUE
      NUMBE2=NUMBE-NUMBE1
C
      DO 112 N=NUMBS1+NUMBS2+1,NUMBS1+NUMBS2+NUMOS
C
      XD=(XEND(N)-XBEG(N))/NUM(N)
      YD=(YEND(N)-YBEG(N))/NUM(N)
C
      SW=SQRT(XD*XD+YD*YD)
C
      DO 112 NE=1,NUM(N)
      NUMBE=NUMBE+1
      M=NUMBE
      XM(M)=XBEG(N)+0.5*(2.0*NE-1.0)*XD
      YM(M)=YBEG(N)+0.5*(2.0*NE-1.0)*YD
      A(M)=0.5*SW
      SINBET(M)=YD/SW
      COSBET(M)=XD/SW
      KOD(M)=KODES(N)
      MN=2*M
      MS=MN-1
      B(MS)=BVS(N)
      B(MN)=BVN(N)
      DIPA(MN)=DPA(N)                                   !array for dip angle
  112 CONTINUE
      NUMBE3=NUMBE-NUMBE2-NUMBE1
```

```
C  ----------------- Output New Elements to the screen ------------------

      PRINT*,        "Boundary element data."
      PRINT*,"Element  Kode  X (Center)  Y (Center)  Length  Angle  US o
     +r SIGMA-S  UN or SIGMA-N  Dip angle"


      DO 115 M=1,NUMBE1+NUMBE2+NUMBE3
      SIZE1=2.0*A(M)
      ANGLE=180.0*ATAN2(SINBET(M),COSBET(M))/PI
      WRITE (*,15) M,KOD(M),XM(M),YM(M),SIZE1,ANGLE,B(2*M-1),B(2*M)
     1,DIPA(2*M)

  115 CONTINUE
   15 FORMAT (I4,I7,2F12.4,F10.2,F7.1,"   ",E10.3,"      ",E10.3
     1,"      ",E10.3)
C     ------------------------------------------------------------------

C  ----------------- Put fixed relative slips in B array ------------------
C                                 into D array

      DO 310 I=2*(NUMBE1+NUMBE2)+1,2*(NUMBE1+NUMBE2+NUMBE3)
      D(I)=B(I)
  310 CONTINUE

C     ------------------------------------------------------------------
C
C
C
C   ----------------------------- 6 -------------------------------
C
C     Compute influence coefficients and set up system of algeraic
C     equations. See comments about matrix elements in 5.
C

      DO 303 I=1,NUMBE1+NUMBE2
      IN=2*I
      IS=IN-1
      XI=XM(I)
      YI=YM(I)
      COSBI=COSBET(I)
      SINBI=SINBET(I)
      KODE=KOD(I)
C
C  Modification to use KODE to specify crack influence coeffs later
C
      IF(KODE.GT.90)  KODE=KODE-100
      IF(KODE.GT.9)then
       KODE=KODE-10
      IF(KODE.GT.0)THEN
      PRINT*,"POSSIBLE KODE ERROR IN ELEMENT",I
      IF(IHALF.EQ.1)THEN
      PRINT*,"CRACKS ARE NOT VALID FOR HALF-SPACE"
      ENDIF
      ENDIF
      ENDIF
C
```

```
      DO 303 J=1,NUMBE1+NUMBE2
      JN=2*J
      JS=JN-1
      CALL initil
      XJ=XM(J)
      YJ=YM(J)
      COSBJ=COSBET(J)
      SINBJ=SINBET(J)
      DIPANG=DIPA(2*J)
      AJ=A(J)
C     Set up region 1 constants
      E=E1
      PR=PR1
      IF(J.GT.NUMBE1)THEN
C     Change to region 2 constants
      E=E2
      PR=PR2
      END IF

c     PRINT*,"KODE=  ",KODE

      CALL coeffs(XI,YI,XJ,YJ,AJ,COSBJ,SINBJ,+1,KOD(I),DIPANG)
      GO TO (240,210,220,230),KSYM
C
  210 XJ=2.0*XSYM-XM(J)
      CALL coeffs(XI,YI,XJ,YJ,AJ,COSBJ,-SINBJ,-1,KOD(I),DIPANG)
      GO TO 240
C
  220 YJ=2.0*YSYM-YM(J)
      CALL coeffs(XI,YI,XJ,YJ,AJ,-COSBJ,SINBJ,-1,KOD(I),DIPANG)
      GO TO 240
C
  230 XJ=2.0*XSYM-XM(J)
      CALL coeffs(XI,YI,XJ,YJ,AJ,COSBJ,-SINBJ,-1,KOD(I),DIPANG)
      XJ=XM(J)
      YJ=2.0*YSYM-YM(J)
      CALL coeffs(XI,YI,XJ,YJ,AJ,-COSBJ,SINBJ,-1,KOD(I),DIPANG)
      XJ=2.0*XSYM-XM(J)
      CALL coeffs(XI,YI,XJ,YJ,AJ,-COSBJ,-SINBJ,+1,KOD(I),DIPANG)
C
  240 GO TO (250,260,270,280,285,286,290,290,290),KODE
C
  250 C(IS,JS)=(SYYS-SXXS)*SINBI*COSBI+SXYS*(COSBI*COSBI-SINBI*SINBI)
!KODE = 1
      C(IS,JN)=(SYYN-SXXN)*SINBI*COSBI+SXYN*(COSBI*COSBI-SINBI*SINBI)
      C(IN,JS)=SXXS*SINBI*SINBI-2.*SXYS*SINBI*COSBI+SYYS*COSBI*COSBI
      C(IN,JN)=SXXN*SINBI*SINBI-2.*SXYN*SINBI*COSBI+SYYN*COSBI*COSBI

c      PRINT*,"SXXS,SYYS,SXYS",SXXS,SYYS,SXYS
c      PRINT*,"SXXN,SYYN,SXYN",SXXN,SYYN,SXYN

      GO TO 300
C
  260 C(IS,JS)=UXS*COSBI+UYS*SINBI
!KODE = 2
      C(IS,JN)=UXN*COSBI+UYN*SINBI
      C(IN,JS)=-UXS*SINBI+UYS*COSBI
```

```
      C(IN,JN)=-UXN*SINBI+UYN*COSBI
      GO TO 300
C
  270 C(IS,JS)=UXS*COSBI+UYS*SINBI
!KODE = 3
      C(IS,JN)=UXN*COSBI+UYN*SINBI
      C(IN,JS)=SXXS*SINBI*SINBI-2.*SXYS*SINBI*COSBI+SYYS*COSBI*COSBI
      C(IN,JN)=SXXN*SINBI*SINBI-2.*SXYN*SINBI*COSBI+SYYN*COSBI*COSBI
      GO TO 300
C
  280 C(IS,JS)=(SYYS-SXXS)*SINBI*COSBI+SXYS*(COSBI*COSBI-SINBI*SINBI)
!KODE = 4
      C(IS,JN)=(SYYN-SXXN)*SINBI*COSBI+SXYN*(COSBI*COSBI-SINBI*SINBI)
      C(IN,JS)=-UXS*SINBI+UYS*COSBI
      C(IN,JN)=-UXN*SINBI+UYN*COSBI
      GO TO 300
C
  285 C(IS,JS)=(SYYS-SXXS)*SINBI*COSBI+SXYS*(COSBI*COSBI-SINBI*SINBI)
!KODE = 5
      C(IS,JN)=(SYYN-SXXN)*SINBI*COSBI+SXYN*(COSBI*COSBI-SINBI*SINBI)
      C(IN,JS)=0.0
      C(IN,JN)=0.0
      IF(IN.EQ.JN) C(IN,JN)=1.0
C     putting this element =1.0 sets D(IN)=B(JN)
      GO TO 300
C
  286 C(IS,JS)=0.0
!KODE = 6
      C(IS,JN)=0.0
      C(IN,JS)=SXXS*SINBI*SINBI-2.*SXYS*SINBI*COSBI+SYYS*COSBI*COSBI
      C(IN,JN)=SXXN*SINBI*SINBI-2.*SXYN*SINBI*COSBI+SYYN*COSBI*COSBI
      IF(IS.EQ.JS) C(IS,JS)=1.0
C     putting this element =1.0 sets D(IS)=B(JS)
C
  300 IF (J.GT.NUMBE1)THEN                                  ! common to kodes
1 to 6
      IF (I.LE.NUMBE1)THEN
      C(IN,JS)=0.0
      C(IN,JN)=0.0
      C(IS,JS)=0.0
      C(IS,JN)=0.0
      END IF
      END IF
      GO TO 301
C
  290 IF(I.GT.NUMBE1)GO TO 291                                !KODE =
7,8,9
      C(IS,JS)=(SYYS-SXXS)*SINBI*COSBI+SXYS*(COSBI*COSBI-SINBI*SINBI)   ! region 1
      C(IS,JN)=(SYYN-SXXN)*SINBI*COSBI+SXYN*(COSBI*COSBI-SINBI*SINBI)
      C(IN,JS)=SXXS*SINBI*SINBI-2.*SXYS*SINBI*COSBI+SYYS*COSBI*COSBI
      C(IN,JN)=SXXN*SINBI*SINBI-2.*SXYN*SINBI*COSBI+SYYN*COSBI*COSBI
      IF(J.GT.NUMBE1)THEN
      IF(KODE.EQ.9)THEN
      C(IS,JS)=0.0
      C(IS,JN)=0.0                                              ! for kode
9
      C(IN,JS)=0.0
```

```
      C(IN,JN)=0.0
      IF(IN.EQ.(JN-2*NUMBE2))THEN                                    ! set
spring rate
      C(IN,JN)=-B(IS)
      ENDIF
      ELSE
      C(IS,JS)=-C(IS,JS)                                             ! region 2
      C(IS,JN)=-C(IS,JN)
      C(IN,JS)=-C(IN,JS)
      C(IN,JN)=-C(IN,JN)
      END IF
      END IF
      GO TO 292
  291 C(IS,JS)=UXS*COSBI+UYS*SINBI                                   !KODE =
7,8,9
      C(IS,JN)=UXN*COSBI+UYN*SINBI
      C(IN,JS)=-UXS*SINBI+UYS*COSBI
      C(IN,JN)=-UXN*SINBI+UYN*COSBI
      IF(J.GT.NUMBE1)THEN
       IF(KODE.EQ.9)THEN
      C(IS,JS)=0.0
      C(IS,JN)=0.0
      C(IN,JS)=0.0
      C(IN,JN)=0.0
      IF(IN.EQ.JN) C(IN,JN)=-1.0
      ELSE
      C(IS,JS)= -C(IS,JS)
      C(IS,JN)= -C(IS,JN)
      C(IN,JS)= -C(IN,JS)
      C(IN,JN)= -C(IN,JN)
      END IF
      END IF
  292 IF((KODE.EQ.8).OR.(KODE.EQ.9))THEN
      IF(J.GT.NUMBE1) THEN
      C(IS,JS)=0.0
      C(IS,JN)=0.0
      END IF
      IF(I.GT.NUMBE1) THEN
      C(IS,JS)=0.0
      C(IS,JN)=0.0
      END IF
      IF(J.GT.NUMBE1) THEN
      IF(I.GT.NUMBE1) THEN
      IF(IS.EQ.JS) C(IS,JS)=1.0                  ! ? self displacement of shear
      END IF
      END IF
      END IF

  301 CONTINUE
  303 CONTINUE

C
C     ------------------------------------------------------------
C
C
C     ------------------------------ 5 ----------------------------------
C      Adjust stress boundary values to account for initial stresses.
```

```
C     This includes stresses due to the pre-existing faults. The latter
C     do not then appear in the Matrix inversion to find D values for
C     the obvious reason that these are specified from the start.

      DO 150 N=1,NUMBE1+NUMBE2
      NN=2*N
      NS=NN-1
      COSB=COSBET(N)
      SINB=SINBET(N)
      XP=XM(N)
      YP=YM(N)

C     Set region 1 constants
      PR=PR1
      E=E1

C     Set-up region 1 loop
      NUMB1=NUMBE1+NUMBE2
      NUMB2=NUMB1+NUMBE3
       CALL Calcpo(XP,YP,UX,UY,SIGXX,SIGYY,SIGXY,NUMB1,NUMB2)
      SIGXX = SIGXX + PXX
      SIGYY = SIGYY + PYY
      SIGXY = SIGXY + PXY
      SIGS=(SIGYY-SIGXX)*SINB*COSB+SIGXY*(COSB*COSB-SINB*SINB)
      SIGN=SIGXX*SINB*SINB-2.0*SIGXY*SINB*COSB+SIGYY*COSB*COSB
      US =  UX*COSB+UY*SINB
      UN = -UX*SINB+UY*COSB
C
C   Print values if wanted
C     PRINT*,"PXX=",PXX
c     PRINT*,"US=",US," SIGS=",SIGS
c     PRINT*,"UN=",UN," SIGN=",SIGN
C
C   The values substituted in B( ) depend on the problem being
C   solved. Note the meaning of the KODES values. Where a value
C   of D is to be specified the corresponding line of the matrix
C   is inactivated by putting all but the diagonal element to
C   zero. The diagonal element is made unity and thus the spec-
C   value of B( ) becomes the corresponding value of D( ).
C
      KODE=KOD(N)
       IF(KODE.GT.90)  KODE=KODE-100
      IF(KODE.GT.9)    KODE=KODE-10

      GO TO (120,125,130,140,145,146,147,147,147),KODE
  120 B(NS)=B(NS)-SIGS
      B(NN)=B(NN)-SIGN
      GO TO 150
  125 B(NS)=B(NS)-US
      B(NN)=B(NN)-UN
      GO TO 150
  130 B(NS)=B(NS)-US
      B(NN)=B(NN)-SIGN
      GO TO 150
  140 B(NS)=B(NS)-SIGS
      B(NN)=B(NN)-UN
      GO TO 150
```

```
  145 B(NS)=B(NS)-SIGS
      GO TO 150
  146 B(NN)=B(NN)-SIGN
      GO TO 150
  147 IF(N.LE.NUMBE1) THEN
      IF(KOD(N).EQ.9) B(NS)=0.0          !  B(NS) contained spring rate
       B(NS)=B(NS)-SIGS
      B(NN)=B(NN)-SIGN
      ENDIF
      IF(N.GT.NUMBE1) THEN
      IF(KOD(N).EQ.9) B(NS)=0.0          !  B(NS) contained spring rate
      B(NS)=0.0  !B(NS)-US
      B(NN)=0.0  !B(NN)-UN
      ENDIF
  150 CONTINUE

         NED=2*(NUMBE1+NUMBE2)


C
C   ------------------------------------------------------------
C
C
C
C
C    ------------------------- 7 ----------------------------
C     Solve system of algebraic equations

      PRINT*,"  Number of matrix lines  =  ",NED

      IF (NED.GT.0) THEN
      CALL SOLVE(NED)
      ENDIF

C
C    ------------------------------------------------------------
C
C
C
C    ------------------------- 8 ----------------------------

c     Prints out the slips for each element.

      PRINT*," "                                !To the screen
      PRINT*," Element displacements:"
      PRINT*," "
      DO 3333 I=1, (NUMBE1+NUMBE2+NUMBE3)
      J=(2*I)-1
      WRITE(*,311)I,D(J),D(J+1),DIPA(J+1)

      if(Matrix)then                            !To a file
      WRITE(7,313)I,tab,XM(I),tab,YM(I),tab,D(J),tab,D(J+1)
     1,tab,DIPA(J+1)
      endif

 3333 CONTINUE
```

```
      if(Matrix)then
       close(7)
       endif
C
  311 FORMAT(I4,") Shear = ",E10.3,"   Normal = ",E10.3
     1,"   Dip angle = ",E10.3)
  313 FORMAT(I4,a1,E10.3,a1,E10.3,a1,E10.3,a1,E10.3,a1,E10.3)

C    +
C    ------------------------------------------------------------
C
C
C
C    -------------------------- 9 ------------------------------


      CLOSE(8)
      PRINT*," "
      PRINT*,"Now select PLOT. If the plot is to be saved as a pict
     +file use PLOT TO SAVE "
      PRINT*,"Detailed plots make very large pict files"
      PRINT*,"A SCREEN PLOT can be saved as a paint file using Opti
     +on-Apple-S  "
      RETURN
      END
C
      SUBROUTINE SOLVE(N)

      IMPLICIT REAL*4(A-H,O-Z)
      COMMON/S10/A(1000,1000),B(1000),X(1000)

      NB=N-1
      DO 20 J=1,NB
      L=J+1
      DO 20 JJ=L,N
      XM=A(JJ,J)/A(J,J)
      DO 10 I=J,N
   10 A(JJ,I)=A(JJ,I)-A(J,I)*XM
   20 B(JJ)=B(JJ)-B(J)*XM

      X(N)=B(N)/A(N,N)
      DO 40 J=1,NB
      JJ=N-J
      L=JJ+1
      SUM=0.0
      DO 30 I=L,N
   30 SUM=SUM+A(JJ,I)*X(I)
   40 X(JJ)=(B(JJ)-SUM)/A(JJ,JJ)

      RETURN
      END
```

```
*****************************************************************************
*
*  clrtty: clear the TTY window and postion the pen at 3,12 (v,h)
*
*****************************************************************************

        subroutine clrtty

        include demo.inc

        INTEGER*4 width,height                    ! for growing windows
        INTEGER*2 scrrect
        COMMON/S20/scrrect(4),width,height

        integer*2 rect(4)
        integer ERASERECT, MOVETO
        parameter (ERASERECT=Z'8A330000',MOVETO=Z'89309000')
        rect(1)=scrrect(1)
        rect(2)=scrrect(2)
        rect(3)=scrrect(3)
        rect(4)=scrrect(4)
        call toolbx(ERASERECT,rect)
        call toolbx(MOVETO,3,12)

        end
```

```
*       COEFFS

      SUBROUTINE coeffs(X,Y,CX,CY,A,COSB,SINB,MSYM,KODE,DIPANG)

      IMPLICIT REAL*4(A-H,O-Z)
      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
      REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
      INTEGER*4 NUM
      COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
     1,BVS(500),BVN(500),DPA(500),NUM(500)
      INTEGER*4 KODES
      COMMON/S7/KODES(500)
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
C  No S 9
C  No S10
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN

      IF(KODE.GT.90) THEN
      CALL coeff3(X,Y,CX,CY,A,COSB,SINB,MSYM,DIPANG)
      ELSE
      IF(KODE.GT.9) THEN
      CALL coeff2(X,Y,CX,CY,A,COSB,SINB,MSYM)
      ELSE
      CALL coeff1(X,Y,CX,CY,A,COSB,SINB,MSYM)
      ENDIF
      ENDIF


      RETURN
      END

      SUBROUTINE coeff1(X,Y,CX,CY,A,COSB,SINB,MSYM)

      IMPLICIT REAL*4(A-H,O-Z)
      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
      REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
      INTEGER*4 NUM
      COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
     1,BVS(500),BVN(500),DPA(500),NUM(500)
      INTEGER*4 KODES
      COMMON/S7/KODES(500)
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
```

```
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
C  No S 9
C  No S10
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN


      CON=1.0/(4.0*PI*(1.0-PR))
      CONS=E/(1.0+PR)
      PRA=1.0-2.0*PR
      PRB=2.0*(1.0-PR)

      COS2B=COSB*COSB-SINB*SINB
      SIN2B=2.0*SINB*COSB
      COSB2=COSB*COSB
      SINB2=SINB*SINB

      XB=(X-CX)*COSB+(Y-CY)*SINB
      YB=-(X-CX)*SINB+(Y-CY)*COSB

      R1S=(XB-A)*(XB-A)+YB*YB
      R2S=(XB+A)*(XB+A)+YB*YB

      IF (R1S.GT.0) FL1=0.5*LOG(R1S)
      ELSE FL1 = 0.0
      IF (R2S.GT.0) FL2=0.5*LOG(R2S)
      ELSE FL2 = 0.0

      FB2=CON*(FL1-FL2)
      IF (YB.NE.0.0) GO TO 10
      FB3=0.0

      IF (ABS(XB).LT.A) FB3=CON*PI

      GO TO 20

   10 FB3=-CON*(ATAN((XB+A)/YB)-ATAN((XB-A)/YB))

   20 FB4=CON*(YB/R1S-YB/R2S)
      FB5=CON*((XB-A)/R1S-(XB+A)/R2S)
      FB6=CON*(((XB-A)**2-YB*YB)/R1S**2-((XB+A)**2-YB*YB)/R2S**2)
      FB7=2.0*CON*YB*((XB-A)/R1S**2-(XB+A)/R2S**2)

      UXDS=-PRA*SINB*FB2+PRB*COSB*FB3+YB*(SINB*FB4-COSB*FB5)
      UXDN=-PRA*COSB*FB2-PRB*SINB*FB3-YB*(COSB*FB4+SINB*FB5)
      UYDS=PRA*COSB*FB2+PRB*SINB*FB3-YB*(COSB*FB4+SINB*FB5)
      UYDN=-PRA*SINB*FB2+PRB*COSB*FB3-YB*(SINB*FB4-COSB*FB5)

      SXXDS=CONS*(2.*COSB2*FB4+SIN2B*FB5+YB*(COS2B*FB6-SIN2B*FB7))
      SXXDN=CONS*(-FB5+YB*(SIN2B*FB6+COS2B*FB7))
      SYYDS=CONS*(2.*SINB2*FB4-SIN2B*FB5-YB*(COS2B*FB6-SIN2B*FB7))
      SYYDN=CONS*(-FB5-YB*(SIN2B*FB6+COS2B*FB7))
      SXYDS=CONS*(SIN2B*FB4-COS2B*FB5+YB*(SIN2B*FB6+COS2B*FB7))
      SXYDN=CONS*(-YB*(COS2B*FB6-SIN2B*FB7))
```

```
      COS2B=COSB*COSB-SINB*SINB
      SIN2B=2.0*SINB*COSB

      SIN3B=3.0*SINB-4.0*SINB**3
      COS3B=4.0*COSB**3-3.0*COSB
      SIN4B=2.0*SIN2B*COS2B
      COS4B=2.0*COS2B*COS2B-1.0

      XB=(X-CX)*COSB+(Y-CY)*SINB
      YB=-(X-CX)*SINB+(Y-CY)*COSB

      UXDSI=PRA*SINB*FI2-PRB*COSB*FI3
     1+(PRC*(Y*SIN2B-YB*SINB)+2.0*Y*SIN2B)*FI4
     2+(PRC*(Y*COS2B-YB*COSB)-Y*(1.0-2.0*COS2B))*FI5
     3+2.0*Y*(Y*SIN3B-YB*SIN2B)*FI6-2*Y*(Y*COS3B-YB*COS2B)*FI7

      UXDNI=PRA*COSB*FI2+PRB*SINB*FI3
     1-(PRC*(Y*COS2B-YB*COSB)-Y)*FI4
     2+PRC*(Y*SIN2B-YB*SINB)*FI5
     3-2.0*Y*(Y*COS3B-YB*COS2B)*FI6-2.0*Y*(Y*SIN3B-YB*SIN2B)*FI7

      UYDSI=-PRA*COSB*FI2-PRB*SINB*FI3
     1-(PRC*(Y*COS2B-YB*COSB)+Y*(1.0-2.0*COS2B))*FI4
     2+(PRC*(Y*SIN2B-YB*SINB)-2.0*Y*SIN2B)*FI5
     3+2.0*Y*(Y*COS3B-YB*COS2B)*FI6+2.0*Y*(Y*SIN3B-YB*SIN2B)*FI7

      UYDNI=PRA*SINB*FI2-PRB*COSB*FI3
     1-PRC*(Y*SIN2B-YB*SINB)*FI4
     2-(PRC*(Y*COS2B-YB*COSB)+Y)*FI5
     3+2.0*Y*(Y*SIN3B-YB*SIN2B)*FI6-2.0*Y*(Y*COS3B-YB*COS2B)*FI7

      SXXDSI=CONS*(FI4-3.0*(COS2B*FI4-SIN2B*FI5)
     1+(2.0*Y*(COSB-3.0*COS3B)+3.0*YB*COS2B)*FI6
     2+(2.0*Y*(SINB-3.0*SIN3B)+3.0*YB*SIN2B)*FI7
     3-2.0*Y*(Y*COS4B-YB*COS3B)*FI8-2.0*Y*(Y*SIN4B-YB*SIN3B)*FI9)

      SXXDNI=CONS*(FI5+(2.0*Y*(SINB-2.0*SIN3B)+3.0*YB*SIN2B)*FI6
     1-(2.0*Y*(COSB-2.0*COS3B)+3.0*YB*COS2B)*FI7
     2-2.0*Y*(Y*SIN4B-YB*SIN3B)*FI8+2.0*Y*(Y*COS4B-YB*COS3B)*FI9)

      SYYDSI=CONS*(FI4-(COS2B*FI4-SIN2B*FI5)
     1-(4.0*Y*SINB*SIN2B-YB*COS2B)*FI6
     2+(4.0*Y*SINB*COS2B+YB*SIN2B)*FI7
     3+2.0*Y*(Y*COS4B-YB*COS3B)*FI8+2.0*Y*(Y*SIN4B-YB*SIN3B)*FI9)

      SYYDNI=CONS*(FI5-(2.0*Y*SINB-YB*SIN2B)*FI6
     1+(2.0*Y*COSB-YB*COS2B)*FI7
     2+2.0*Y*(Y*SIN4B-YB*SIN3B)*FI8-2.0*Y*(Y*COS4B-YB*COS3B)*FI9)

      SXYDSI=CONS*(SIN2B*FI4+COS2B*FI5
     1+(2.0*Y*SINB*(1.0+4.0*COS2B)-YB*SIN2B)*FI6
     2+(2.0*Y*COSB*(3.0-4.0*COS2B)+YB*COS2B)*FI7
     3+2.0*Y*(Y*SIN4B-YB*SIN3B)*FI8-2.0*Y*(Y*COS4B-YB*COS3B)*FI9)

      SXYDNI=CONS*((4.0*Y*SINB*SIN2B+YB*COS2B)*FI6
     1-(4.0*Y*SINB*COS2B-YB*SIN2B)*FI7
     2-2.0*Y*(Y*COS4B-YB*COS3B)*FI8-2.0*Y*(Y*SIN4B-YB*SIN3B)*FI9)
```

```
  555 UXS=UXS+MSYM*UXDS+UXDSI
      UXN=UXN+UXDN+UXDNI
      UYS=UYS+MSYM*UYDS+UYDSI
      UYN=UYN+UYDN+UYDNI

      SXXS=SXXS+MSYM*SXXDS+SXXDSI
      SXXN=SXXN+SXXDN+SXXDNI
      SYYS=SYYS+MSYM*SYYDS+SYYDSI
      SYYN=SYYN+SYYDN+SYYDNI
      SXYS=SXYS+MSYM*SXYDS+SXYDSI
      SXYN=SXYN+SXYDN+SXYDNI


C     AREA=SXXN+SYYN
C     PRINT*,"PR=",PR," CON=",CON," AREA=",AREA

      RETURN
      END



      SUBROUTINE coeff2(X,Y,CX,CY,A,COSB,SINB,MSYM)

      IMPLICIT REAL*4(A-H,O-Z)
      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
      REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
      INTEGER*4 NUM
      COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
     1,BVS(500),BVN(500),DPA(500),NUM(500)
      INTEGER*4 KODES
      COMMON/S7/KODES(500)
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
C  No S 9
C  No S10
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN

      CON=1.0/(4.0*PI*(1.0-PR))
      CONS=E/(1.0+PR)

      COS2B=COSB*COSB-SINB*SINB
      SIN2B=2.0*SINB*COSB
      COSB2=COSB*COSB
      SINB2=SINB*SINB

      XB= (X-CX)*COSB+(Y-CY)*SINB
```

```
YB=-(X-CX)*SINB+(Y-CY)*COSB

XB=-XB
YB=-YB

AA= CONS/4.0/A/(1.0-PR)
BB= 1.0/4.0/A/(1.0-PR)

RS =SQRT(XB*XB+YB*YB)
R1S=SQRT((XB-A)*(XB-A)+YB*YB)
R2S=SQRT((XB+A)*(XB+A)+YB*YB)
BRS=SQRT(R1S*R2S)

XXB=ABS(XB)
IF(XXB.LE.A.AND.YB.EQ.0.0)THEN


UXBDS=   (SQRT(A*A-XB*XB))/A/2.0
UXBDN=  -(1.0-2.0*PR)/4.0/(1.0-PR)*XB/A
UYBDS=   (1.0-2.0*PR)/4.0/(1.0-PR)*XB/A
UYBDN=   (SQRT(A*A-XB*XB))/A/2.0

IF(XXB.EQ.A)THEN
SXXBDS=0.0
ELSE
SXXBDS= -2*AA*XB/SQRT(A*A-XB*XB)
ENDIF
SXXBDN= -AA
SYYBDS= 0.0
SYYBDN= -AA
SXYBDS= -AA
SXYBDN= 0.0

ELSE

STH = YB/RS
STH1= YB/R1S
STH2= YB/R2S
CTH = XB/RS
CTH1= (XB-A)/R1S
CTH2= (XB+A)/R2S

C2BTH= (CTH1*CTH2)-(STH1*STH2)
S2BTH= (STH1*CTH2)+(CTH1*STH2)

ARG1= ((1.0-C2BTH)/2.0)
ARG2= ((1.0+C2BTH)/2.0)
IF(ARG1.LE.0.0)ARG1=0.0
IF(ARG2.LE.0.0)ARG2=0.0


SBTH=SQRT(ARG1)
CBTH=SQRT(ARG2)

IF(S2BTH.EQ.0.0.AND.YB.EQ.0.) THEN
IF(XB.LT.0.0) CBTH=-CBTH
ENDIF
```

```
      IF(S2BTH.LE.0.0.AND.YB.GT.0.0) CBTH=-CBTH
      IF(S2BTH.GE.0.0.AND.YB.LT.0.0) CBTH=-CBTH

      IF(S2BTH.GE.0.0.AND.YB.LT.0.0) SBTH=-SBTH
      IF(S2BTH.LT.0.0.AND.YB.LT.0.0) SBTH=-SBTH

      SDIF=STH*CBTH-CTH*SBTH
      CDIF=CTH*CBTH+STH*SBTH

      S3BTH=3.0*SBTH-4.0*SBTH*SBTH*SBTH
      C3BTH=4.0*CBTH*CBTH*CBTH-3.0*CBTH

      F1=2*(1.0-PR)*(BRS*SBTH-RS*STH)
      F3=(1.0-2.0*PR)*(BRS*CBTH-RS*CTH)
      F2=RS*STH*((RS/BRS*CDIF)-1.0)
      F4=RS*STH*RS/BRS*SDIF

      G1=(RS/BRS*CDIF)-1.0
      G2=A*A*RS*STH*S3BTH/(BRS*BRS*BRS)
      G3=A*A*RS*STH*C3BTH/(BRS*BRS*BRS)
      G4=2.0*RS*SDIF/BRS

      UXBDS=  BB*(F1+F2)
      UXBDN=  BB*(F3-F4)
      UYBDS= -BB*(F3+F4)
      UYBDN=  BB*(F1-F2)

      SXXBDS= AA*(G4-G3)
      SXXBDN= AA*(G1-G2)
      SYYBDS= AA*G3
      SYYBDN= AA*(G1+G2)
      SXYBDS= AA*(G1-G2)
      SXYBDN= AA*G3

      ENDIF

      UXDS=UXBDS*COSB-UYBDS*SINB
      UXDN=UXBDN*COSB-UYBDN*SINB
      UYDS=UXBDS*SINB+UYBDS*COSB
      UYDN=UXBDN*SINB+UYBDN*COSB

c      PRINT*,"XB=",XB," YB=",YB

c      PRINT*,"UXBDS=",UXBDS," UYBDS=",UYBDS
c      PRINT*,"SXXBDS=",SXXBDS," SYYBDS=",SYYBDS," SXYBDS=",SXYBDS

c       PRINT*,"UXBDN=",UXBDN," UYBDN=",UYBDN
c       PRINT*,"SXXBDN=",SXXBDN," SYYBDN=",SYYBDN," SXYBDN=",SXYBDN
c       PRINT*," "

      SXXDS=SXXBDS*COSB2-SXYBDS*SIN2B+SYYBDS*SINB2
      SXXDN=SXXBDN*COSB2-SXYBDN*SIN2B+SYYBDN*SINB2

      SYYDS=SXXBDS*SINB2-SXYBDS*SIN2B+SYYBDS*COSB2
      SYYDN=SXXBDN*SINB2+SXYBDN*SIN2B+SYYBDN*COSB2
```

```
      SXYDS= 0.5*(SXXBDS-SYYBDS)*SIN2B+SXYBDS*COS2B
      SXYDN= 0.5*(SXXBDN-SYYBDN)*SIN2B+SXYBDN*COS2B

c     PRINT*,"SXXDS=",SXXDS," SXXDN=",SXXDN
c     PRINT*,"SYYDS=",SYYDS," SYYDN=",SYYDN
c     PRINT*,"SXYDS=",SXYDS," SXYDN=",SXYDN


  555 UXS=UXS+MSYM*UXDS
      UXN=UXN+UXDN
      UYS=UYS+MSYM*UYDS
      UYN=UYN+UYDN

      SXXS=SXXS-MSYM*SXXDS
      SXXN=SXXN-SXXDN
      SYYS=SYYS-MSYM*SYYDS
      SYYN=SYYN-SYYDN
      SXYS=SXYS-MSYM*SXYDS
      SXYN=SXYN-SXYDN



      RETURN
      END


       SUBROUTINE coeff3(XX,YY,CX,CY,A,COSB,SINB,MSYM,DIPANG)

      IMPLICIT REAL*4(A-H,O-Z)
      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
      REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
      INTEGER*4 NUM
      COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
     1,BVS(500),BVN(500),DPA(500),NUM(500)
      INTEGER*4 KODES
      COMMON/S7/KODES(500)
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
C  No S 9
C  No S10
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN

      XB=  (XX-CX)*COSB+(YY-CY)*SINB
      YB= -(XX-CX)*SINB+(YY-CY)*COSB

      XB = -XB
      YB = -YB
```

```
      COS2B=COSB*COSB-SINB*SINB
      SIN2B=2.0*SINB*COSB
      COSB2=COSB*COSB
      SINB2=SINB*SINB

          ALPHA  =  1.0/(2.0*(1.0-PR1))
          X= XB
          Y= YB  - ZDEPTH/2.0/TAN(DIPANG*PI/180.0)

************  You can change these values:-

          Z  =   - ZDEPTH/2.0            !depth at which components are determined.
                                         !This must be negative
          DEPTH  =   ZDEPTH/2.0          !to centre of dislocaton surface
          DIPP   =  180.0-DIPANG
          AL1    =  A
          AL2    =  A
          AW1    =  ZDEPTH/2.0/SIN(DIPANG*PI/180.0)              ! Downdip fault
width
          AW2    =  ZDEPTH/2.0/SIN(DIPANG*PI/180.0)              ! Updip fault
width

************

          DISL1    =  -1.0
          DISL2    =  0.0
          DISL3    =  0.0


      CALL        DC3D(ALPHA,X,Y,Z,DEPTH,DIPP,
     *              AL1,AL2,AW1,AW2,DISL1,DISL2,DISL3,
     *              UX,UY,UZ,UXX,UYX,UZX,UXY,UYY,UZY,
     *              UXZ,UYZ,UZZ,IRET)


      UXBDS= UX
      UYBDS= UY

      SXXBDS=  (E1/(1.0+PR1)*((PR1/(1.0-2.0*PR1))*(UXX+UYY+UZZ) + UXX))
      SYYBDS=  (E1/(1.0+PR1)*((PR1/(1.0-2.0*PR1))*(UXX+UYY+UZZ) + UYY))
      SXYBDS=  (E1/(2.0*(1.0+PR1))) * (UXY+UYX)

          DISL1    =  0.0
          DISL2    = -1.0
          DISL3    =  0.0
c      PRINT*,"DEPTH=  ",ZDEPTH,"   DISL2= ",DISL2, " DIP= ",DIPANG
      CALL        DC3D(ALPHA,X,Y,Z,DEPTH,DIPP,
     *              AL1,AL2,AW1,AW2,DISL1,DISL2,DISL3,
     *              UX,UY,UZ,UXX,UYX,UZX,UXY,UYY,UZY,
     *              UXZ,UYZ,UZZ,IRET)

      UXBDN= UX
      UYBDN= UY


      SXXBDN=  (E1/(1.0+PR1)*((PR1/(1.0-2.0*PR1))*(UXX+UYY+UZZ) + UXX))
```

```
      SYYBDN=   (E1/(1.0+PR1)*((PR1/(1.0-2.0*PR1))*(UXX+UYY+UZZ) + UYY))
      SXYBDN=   (E1/(2.0*(1.0+PR1))) * (UXY+UYX)

c      PRINT*,"XB=",XB," YB=",YB

c      PRINT*,"*UXBDS=",UXBDS," *UYBDS=",UYBDS
c      PRINT*,"SXXBDS=",SXXBDS," SYYBDS=",SYYBDS," SXYBDS=",SXYBDS

c       PRINT*,"*UXBDN=",UXBDN," *UYBDN=",UYBDN
c       PRINT*,"SXXBDN=",SXXBDN," SYYBDN=",SYYBDN," SXYBDN=",SXYBDN
c       PRINT*," "

      UXDS=UXBDS*COSB-UYBDS*SINB
      UXDN=UXBDN*COSB-UYBDN*SINB
      UYDS=UXBDS*SINB+UYBDS*COSB
      UYDN=UXBDN*SINB+UYBDN*COSB

c      PRINT*,"UXDS=",UXDS," UXDN=",UXDN
c      PRINT*,"UYDS=",UYDS," UYDN=",UYDN

c      PRINT*,"SXXBDS=",SXXBDS," SXXBDN=",SXXBDN
c      PRINT*,"SYYBDS=",SYYBDS," SYYBDN=",SYYBDN
c      PRINT*,"SXYBDS=",SXYBDS," SXYBDN=",SXYBDN
c      PRINT*," "

      SXXDS= SXXBDS*COSB2-SXYBDS*SIN2B+SYYBDS*SINB2
      SXXDN= SXXBDN*COSB2-SXYBDN*SIN2B+SYYBDN*SINB2

      SYYDS= SXXBDS*SINB2+SXYBDS*SIN2B+SYYBDS*COSB2
      SYYDN= SXXBDN*SINB2+SXYBDN*SIN2B+SYYBDN*COSB2

      SXYDS=  0.5*(SXXBDS-SYYBDS)*SIN2B+SXYBDS*COS2B
      SXYDN=  0.5*(SXXBDN-SYYBDN)*SIN2B+SXYBDN*COS2B

c      PRINT*,"SXXDS=",SXXDS," SXXDN=",SXXDN
c      PRINT*,"SYYDS=",SYYDS," SYYDN=",SYYDN
c      PRINT*,"SXYDS=",SXYDS," SXYDN=",SXYDN


  555 UXS=UXS+MSYM*UXDS
      UXN=UXN+UXDN
      UYS=UYS+MSYM*UYDS
      UYN=UYN+UYDN

      SXXS=SXXS-MSYM*SXXDS
      SXXN=SXXN-SXXDN
      SYYS=SYYS-MSYM*SYYDS
      SYYN=SYYN-SYYDN
      SXYS=SXYS-MSYM*SXYDS
      SXYN=SXYN-SXYDN


      RETURN
      END
```

```
      SUBROUTINE  DC3D(ALPHA,X,Y,Z,DEPTH,DIP,                           04610000
     *              AL1,AL2,AW1,AW2,DISL1,DISL2,DISL3,                  04620002
     *              UX,UY,UZ,UXX,UYX,UZX,UXY,UYY,UZY,UXZ,UYZ,UZZ,IRET)  04630002
      IMPLICIT REAL*8 (A-H,O-Z)                                         04640000
      REAL*4   ALPHA,X,Y,Z,DEPTH,DIP,AL1,AL2,AW1,AW2,DISL1,DISL2,DISL3, 04650000
     *         UX,UY,UZ,UXX,UYX,UZX,UXY,UYY,UZY,UXZ,UYZ,UZZ             04660000
C                                                                       04670000
C*********************************************************************  04680000
C*****                                                           *****  04690000
C*****    DISPLACEMENT AND STRAIN AT DEPTH                       *****  04700000
C*****    DUE TO BURIED FINITE FAULT IN A SEMIINFINITE MEDIUM    *****  04710000
C*****                          CODED BY  Y.OKADA ... SEP 1991   *****  04720002
C*****                          REVISED   Y.OKADA ... NOV 1991   *****  04730002
C*****                                                           *****  04740000
C*********************************************************************  04750000
C                                                                       04760000
C***** INPUT                                                            04770000
C*****   ALPHA : MEDIUM CONSTANT  (LAMBDA+MYU)/(LAMBDA+2*MYU)           04780000
C*****   X,Y,Z : COORDINATE OF OBSERVING POINT                          04790000
C*****   DEPTH : SOURCE DEPTH                                           04800000
C*****   DIP   : DIP-ANGLE (DEGREE)                                     04810000
C*****   AL1,AL2    : FAULT LENGTH (-STRIKE,+STRIKE)                    04820000
C*****   AW1,AW2    : FAULT WIDTH  ( DOWNDIP, UPDIP)                    04830000
C*****   DISL1-DISL3 : STRIKE-, DIP-, TENSILE-DISLOCATIONS              04840000
C                                                                       04850000
C***** OUTPUT                                                           04860000
C*****   UX, UY, UZ  : DISPLACEMENT ( UNIT=(UNIT OF DISL)               04870000
C*****   UXX,UYX,UZX : X-DERIVATIVE ( UNIT=(UNIT OF DISL) /             04880000
C*****   UXY,UYY,UZY : Y-DERIVATIVE        (UNIT OF X,Y,Z,DEPTH,AL,AW) )04890000
C*****   UXZ,UYZ,UZZ : Z-DERIVATIVE                                     04900000
C*****   IRET        : RETURN CODE  ( =0....NORMAL,   =1....SINGULAR )  04910002
C                                                                       04920000
      COMMON /C0/DUMMY(5),SD,CD                                         04930000
      COMMON /C2/XI2,ET2,Q2,R                                           04940000
      DIMENSION  U(12),DU(12),DUA(12),DUB(12),DUC(12)                   04950000
      DATA  F0/0.D0/                                                    04960000
C-----                                                                  04970000
      IF(Z.GT.0.) WRITE(6,'('' ** POSITIVE Z WAS GIVEN IN SUB-DC3D'')') 04980000
      DO 111 I=1,12                                                     04990000
        U  (I)=F0                                                       05000000
        DUA(I)=F0                                                       05010000
        DUB(I)=F0                                                       05020000
        DUC(I)=F0                                                       05030000
  111 CONTINUE                                                          05040000
      AALPHA=ALPHA                                                      05050000
      DDIP=DIP                                                          05060000
      CALL DCCON0(AALPHA,DDIP)                                          05070000
C=================================                                      05080000
C=====  REAL-SOURCE CONTRIBUTION  =====                                 05090000
C=================================                                      05100000
      D=DEPTH+Z                                                         05110000
      P=Y*CD+D*SD                                                       05120000
      Q=Y*SD-D*CD                                                       05130000
      JXI=0                                                             05140000
      JET=0                                                             05150000
      IF((X+AL1)*(X-AL2).LE.0.) JXI=1                                   05160000
      IF((P+AW1)*(P-AW2).LE.0.) JET=1                                   05170000
```

```
      DD1=DISL1                                                         05180000
      DD2=DISL2                                                         05190000
      DD3=DISL3                                                         05200000
C-----                                                                  05210000
      DO 223 K=1,2                                                      05220000
      IF(K.EQ.1) ET=P+AW1                                               05230000
      IF(K.EQ.2) ET=P-AW2                                               05240000
      DO 222 J=1,2                                                      05250000
        IF(J.EQ.1) XI=X+AL1                                             05260000
        IF(J.EQ.2) XI=X-AL2                                             05270000
        CALL DCCON2(XI,ET,Q,SD,CD)                                      05280002
        IF(JXI.EQ.1 .AND. Q.EQ.F0 .AND. ET.EQ.F0) GO TO 99              05290002
        IF(JET.EQ.1 .AND. Q.EQ.F0 .AND. XI.EQ.F0) GO TO 99              05300002
        CALL UA(XI,ET,Q,DD1,DD2,DD3,DUA)                                05310000
C-----                                                                  05320000
        DO 220 I=1,10,3                                                 05330000
          DU(I)  =-DUA(I)                                               05340000
          DU(I+1)=-DUA(I+1)*CD+DUA(I+2)*SD                              05350000
          DU(I+2)=-DUA(I+1)*SD-DUA(I+2)*CD                              05360000
          IF(I.LT.10) GO TO 220                                         05370000
          DU(I)  =-DU(I)                                                05380000
          DU(I+1)=-DU(I+1)                                              05390000
          DU(I+2)=-DU(I+2)                                              05400000
  220   CONTINUE                                                        05410000
        DO 221 I=1,12                                                   05420000
          IF(J+K.NE.3) U(I)=U(I)+DU(I)                                  05430000
          IF(J+K.EQ.3) U(I)=U(I)-DU(I)                                  05440000
  221   CONTINUE                                                        05450000
C-----                                                                  05460000
  222 CONTINUE                                                          05470000
  223 CONTINUE                                                          05480000
C=================================                                      05490000
C=====  IMAGE-SOURCE CONTRIBUTION  =====                                05500000
C=================================                                      05510000
      ZZ=Z                                                              05520000
      D=DEPTH-Z                                                         05530000
      P=Y*CD+D*SD                                                       05540000
      Q=Y*SD-D*CD                                                       05550000
      JET=0                                                             05560000
      IF((P+AW1)*(P-AW2).LE.0.) JET=1                                   05570000
C-----                                                                  05580000
      DO 334 K=1,2                                                      05590000
      IF(K.EQ.1) ET=P+AW1                                               05600000
      IF(K.EQ.2) ET=P-AW2                                               05610000
      DO 333 J=1,2                                                      05620000
        IF(J.EQ.1) XI=X+AL1                                             05630000
        IF(J.EQ.2) XI=X-AL2                                             05640000
        CALL DCCON2(XI,ET,Q,SD,CD)                                      05650002
        CALL UA(XI,ET,Q,DD1,DD2,DD3,DUA)                                05660000
        CALL UB(XI,ET,Q,DD1,DD2,DD3,DUB)                                05670000
        CALL UC(XI,ET,Q,ZZ,DD1,DD2,DD3,DUC)                             05680000
C-----                                                                  05690000
        DO 330 I=1,10,3                                                 05700000
          DU(I)=DUA(I)+DUB(I)+Z*DUC(I)                                  05710000
          DU(I+1)=(DUA(I+1)+DUB(I+1)+Z*DUC(I+1))*CD                     05720000
     *            -(DUA(I+2)+DUB(I+2)+Z*DUC(I+2))*SD                    05730000
          DU(I+2)=(DUA(I+1)+DUB(I+1)-Z*DUC(I+1))*SD                     05740000
```

```
     *            +(DUA(I+2)+DUB(I+2)-Z*DUC(I+2))*CD
          IF(I.LT.10) GO TO 330
          DU(10)=DU(10)+DUC(1)
          DU(11)=DU(11)+DUC(2)*CD-DUC(3)*SD
          DU(12)=DU(12)+DUC(2)*SD-DUC(3)*CD
  330   CONTINUE
        DO 331 I=1,12
          IF(J+K.NE.3) U(I)=U(I)+DU(I)
          IF(J+K.EQ.3) U(I)=U(I)-DU(I)
  331   CONTINUE
C-----
  333 CONTINUE
  334 CONTINUE
C=====
      UX=U(1)
      UY=U(2)
      UZ=U(3)
      UXX=U(4)
      UYX=U(5)
      UZX=U(6)
      UXY=U(7)
      UYY=U(8)
      UZY=U(9)
      UXZ=U(10)
      UYZ=U(11)
      UZZ=U(12)
      IRET=0
      RETURN
C==================================
C=====  IN CASE OF SINGULAR (R=0)  =====
C==================================
   99 UX=F0
      UY=F0
      UZ=F0
      UXX=F0
      UYX=F0
      UZX=F0
      UXY=F0
      UYY=F0
      UZY=F0
      UXZ=F0
      UYZ=F0
      UZZ=F0
      IRET=1
      RETURN
      END
      SUBROUTINE  UA(XI,ET,Q,DISL1,DISL2,DISL3,U)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION U(12),DU(12)
C
C*********************************************************************
C*****    DISPLACEMENT AND STRAIN AT DEPTH (PART-A)            *****
C*****    DUE TO BURIED FINITE FAULT IN A SEMIINFINITE MEDIUM  *****
C*********************************************************************
C
C***** INPUT
C*****   XI,ET,Q : STATION COORDINATES IN FAULT SYSTEM
```

```
C*****   DISL1-DISL3 : STRIKE-, DIP-, TENSILE-DISLOCATIONS                 06320000
C***** OUTPUT                                                              06330000
C*****   U(12) : DISPLACEMENT AND THEIR DERIVATIVES                        06340000
C                                                                          06350000
      COMMON /C0/ALP1,ALP2,ALP3,ALP4,ALP5,SD,CD,SDSD,CDCD,SDCD,S2D,C2D    06360000
      COMMON /C2/XI2,ET2,Q2,R,R2,R3,R5,Y,D,TT,ALX,ALE,X11,Y11,X32,Y32,    06370000
     *           EY,EZ,FY,FZ,GY,GZ,HY,HZ                                  06380000
      DATA F0,F2,PI2/0.D0,2.D0,6.283185307179586D0/                        06390000
C-----                                                                     06400000
      DO 111  I=1,12                                                       06410000
  111 U(I)=F0                                                              06420000
      XY=XI*Y11                                                            06430000
      QX=Q *X11                                                            06440000
      QY=Q *Y11                                                            06450000
C=================================                                         06460000
C=====  STRIKE-SLIP CONTRIBUTION  =====                                   06470000
C=================================                                         06480000
      IF(DISL1.NE.F0) THEN                                                 06490000
        DU( 1)=    TT/F2 +ALP2*XI*QY                                       06500000
        DU( 2)=           ALP2*Q/R                                         06510000
        DU( 3)= ALP1*ALE -ALP2*Q*QY                                        06520000
        DU( 4)=-ALP1*QY  -ALP2*XI2*Q*Y32                                   06530000
        DU( 5)=          -ALP2*XI*Q/R3                                     06540000
        DU( 6)= ALP1*XY  +ALP2*XI*Q2*Y32                                   06550000
        DU( 7)= ALP1*XY*SD        +ALP2*XI*FY+D/F2*X11                     06560000
        DU( 8)=                    ALP2*EY                                 06570000
        DU( 9)= ALP1*(CD/R+QY*SD) -ALP2*Q*FY                               06580000
        DU(10)= ALP1*XY*CD        +ALP2*XI*FZ+Y/F2*X11                     06590000
        DU(11)=                    ALP2*EZ                                 06600000
        DU(12)=-ALP1*(SD/R-QY*CD) -ALP2*Q*FZ                               06610000
        DO 222 I=1,12                                                      06620000
  222   U(I)=U(I)+DISL1/PI2*DU(I)                                          06630000
      ENDIF                                                                06640000
C=================================                                         06650000
C=====    DIP-SLIP CONTRIBUTION   =====                                   06660000
C=================================                                         06670000
      IF(DISL2.NE.F0) THEN                                                 06680000
        DU( 1)=           ALP2*Q/R                                         06690000
        DU( 2)=    TT/F2 +ALP2*ET*QX                                       06700000
        DU( 3)= ALP1*ALX -ALP2*Q*QX                                        06710000
        DU( 4)=         -ALP2*XI*Q/R3                                      06720000
        DU( 5)= -QY/F2 -ALP2*ET*Q/R3                                       06730000
        DU( 6)= ALP1/R +ALP2*Q2/R3                                         06740000
        DU( 7)=                    ALP2*EY                                 06750000
        DU( 8)= ALP1*D*X11+XY/F2*SD +ALP2*ET*GY                            06760000
        DU( 9)= ALP1*Y*X11          -ALP2*Q*GY                             06770000
        DU(10)=                     ALP2*EZ                                06780000
        DU(11)= ALP1*Y*X11+XY/F2*CD +ALP2*ET*GZ                            06790000
        DU(12)=-ALP1*D*X11          -ALP2*Q*GZ                             06800000
        DO 333 I=1,12                                                      06810000
  333   U(I)=U(I)+DISL2/PI2*DU(I)                                          06820000
      ENDIF                                                                06830000
C=================================                                         06840000
C=====  TENSILE-FAULT CONTRIBUTION  =====                                 06850000
C=================================                                         06860000
      IF(DISL3.NE.F0) THEN                                                 06870000
        DU( 1)=-ALP1*ALE -ALP2*Q*QY                                        06880000
```

```
      DU( 2)=-ALP1*ALX -ALP2*Q*QX                                       06890000
      DU( 3)=    TT/F2 -ALP2*(ET*QX+XI*QY)                              06900000
      DU( 4)=-ALP1*XY  +ALP2*XI*Q2*Y32                                  06910000
      DU( 5)=-ALP1/R   +ALP2*Q2/R3                                      06920000
      DU( 6)=-ALP1*QY  -ALP2*Q*Q2*Y32                                   06930000
      DU( 7)=-ALP1*(CD/R+QY*SD)  -ALP2*Q*FY                             06940000
      DU( 8)=-ALP1*Y*X11         -ALP2*Q*GY                             06950000
      DU( 9)= ALP1*(D*X11+XY*SD) +ALP2*Q*HY                             06960000
      DU(10)= ALP1*(SD/R-QY*CD)  -ALP2*Q*FZ                             06970000
      DU(11)= ALP1*D*X11         -ALP2*Q*GZ                             06980000
      DU(12)= ALP1*(Y*X11+XY*CD) +ALP2*Q*HZ                             06990000
      DO 444 I=1,12                                                     07000000
  444 U(I)=U(I)+DISL3/PI2*DU(I)                                         07010000
     ENDIF                                                              07020000
     RETURN                                                             07030000
     END                                                                07040000
     SUBROUTINE  UB(XI,ET,Q,DISL1,DISL2,DISL3,U)                        07050000
     IMPLICIT REAL*8 (A-H,O-Z)                                          07060000
     DIMENSION U(12),DU(12)                                             07070000
C                                                                       07080000
C*********************************************************************  07090000
C*****    DISPLACEMENT AND STRAIN AT DEPTH (PART-B)              *****  07100000
C*****    DUE TO BURIED FINITE FAULT IN A SEMIINFINITE MEDIUM    *****  07110000
C*********************************************************************  07120000
C                                                                       07130000
C***** INPUT                                                            07140000
C*****   XI,ET,Q : STATION COORDINATES IN FAULT SYSTEM                  07150000
C*****   DISL1-DISL3 : STRIKE-, DIP-, TENSILE-DISLOCATIONS              07160000
C***** OUTPUT                                                           07170000
C*****   U(12) : DISPLACEMENT AND THEIR DERIVATIVES                     07180000
C                                                                       07190000
     COMMON /C0/ALP1,ALP2,ALP3,ALP4,ALP5,SD,CD,SDSD,CDCD,SDCD,S2D,C2D  07200000
     COMMON /C2/XI2,ET2,Q2,R,R2,R3,R5,Y,D,TT,ALX,ALE,X11,Y11,X32,Y32,   07210000
    *           EY,EZ,FY,FZ,GY,GZ,HY,HZ                                 07220000
     DATA  F0,F1,F2,PI2/0.D0,1.D0,2.D0,6.283185307179586D0/             07230000
C-----                                                                  07240000
     RD=R+D                                                             07250000
     D11=F1/(R*RD)                                                      07260000
     AJ2=XI*Y/RD*D11                                                    07270000
     AJ5=-(D+Y*Y/RD)*D11                                                07280000
     IF(CD.NE.F0) THEN                                                  07290000
       IF(XI.EQ.F0) THEN                                                07300000
         AI4=F0                                                         07310000
       ELSE                                                             07320000
         X=DSQRT(XI2+Q2)                                                07330000
         AI4=F1/CDCD*( XI/RD*SDCD                                       07340000
    *        +F2*DATAN((ET*(X+Q*CD)+X*(R+X)*SD)/(XI*(R+X)*CD)) )        07350000
       ENDIF                                                            07360000
       AI3=(Y*CD/RD-ALE+SD*DLOG(RD))/CDCD                               07370000
       AK1=XI*(D11-Y11*SD)/CD                                           07380000
       AK3=(Q*Y11-Y*D11)/CD                                             07390000
       AJ3=(AK1-AJ2*SD)/CD                                              07400000
       AJ6=(AK3-AJ5*SD)/CD                                              07410000
     ELSE                                                               07420000
       RD2=RD*RD                                                        07430000
       AI3=(ET/RD+Y*Q/RD2-ALE)/F2                                       07440000
       AI4=XI*Y/RD2/F2                                                  07450000
```

```
        AK1=XI*Q/RD*D11                                                 07460000
        AK3=SD/RD*(XI2*D11-F1)                                          07470000
        AJ3=-XI/RD2*(Q2*D11-F1/F2)                                      07480000
        AJ6=-Y/RD2*(XI2*D11-F1/F2)                                      07490000
      ENDIF                                                             07500000
C-----                                                                  07510000
      XY=XI*Y11                                                         07520000
      AI1=-XI/RD*CD-AI4*SD                                              07530000
      AI2= DLOG(RD)+AI3*SD                                              07540000
      AK2= F1/R+AK3*SD                                                  07550000
      AK4= XY*CD-AK1*SD                                                 07560000
      AJ1= AJ5*CD-AJ6*SD                                                07570000
      AJ4=-XY-AJ2*CD+AJ3*SD                                             07580000
C-----                                                                  07590000
      DO 111  I=1,12                                                    07600000
  111 U(I)=F0                                                           07610000
      QX=Q*X11                                                          07620000
      QY=Q*Y11                                                          07630000
C=================================                                      07640000
C=====  STRIKE-SLIP CONTRIBUTION  =====                                 07650000
C=================================                                      07660000
      IF(DISL1.NE.F0) THEN                                              07670000
        DU( 1)=-XI*QY-TT -ALP3*AI1*SD                                   07680000
        DU( 2)=-Q/R      +ALP3*Y/RD*SD                                  07690000
        DU( 3)= Q*QY     -ALP3*AI2*SD                                   07700000
        DU( 4)= XI2*Q*Y32 -ALP3*AJ1*SD                                  07710000
        DU( 5)= XI*Q/R3   -ALP3*AJ2*SD                                  07720000
        DU( 6)=-XI*Q2*Y32 -ALP3*AJ3*SD                                  07730000
        DU( 7)=-XI*FY-D*X11 +ALP3*(XY+AJ4)*SD                           07740000
        DU( 8)=-EY          +ALP3*(F1/R+AJ5)*SD                         07750000
        DU( 9)= Q*FY        -ALP3*(QY-AJ6)*SD                           07760000
        DU(10)=-XI*FZ-Y*X11 +ALP3*AK1*SD                                07770000
        DU(11)=-EZ          +ALP3*Y*D11*SD                              07780000
        DU(12)= Q*FZ        +ALP3*AK2*SD                                07790000
        DO 222 I=1,12                                                   07800000
  222   U(I)=U(I)+DISL1/PI2*DU(I)                                       07810000
      ENDIF                                                             07820000
C=================================                                      07830000
C=====   DIP-SLIP CONTRIBUTION   =====                                  07840000
C=================================                                      07850000
      IF(DISL2.NE.F0) THEN                                              07860000
        DU( 1)=-Q/R      +ALP3*AI3*SDCD                                 07870000
        DU( 2)=-ET*QX-TT -ALP3*XI/RD*SDCD                               07880000
        DU( 3)= Q*QX     +ALP3*AI4*SDCD                                 07890000
        DU( 4)= XI*Q/R3     +ALP3*AJ4*SDCD                              07900000
        DU( 5)= ET*Q/R3+QY  +ALP3*AJ5*SDCD                              07910000
        DU( 6)=-Q2/R3       +ALP3*AJ6*SDCD                              07920000
        DU( 7)=-EY          +ALP3*AJ1*SDCD                              07930000
        DU( 8)=-ET*GY-XY*SD +ALP3*AJ2*SDCD                              07940000
        DU( 9)= Q*GY        +ALP3*AJ3*SDCD                              07950000
        DU(10)=-EZ          -ALP3*AK3*SDCD                              07960000
        DU(11)=-ET*GZ-XY*CD -ALP3*XI*D11*SDCD                           07970000
        DU(12)= Q*GZ        -ALP3*AK4*SDCD                              07980000
        DO 333 I=1,12                                                   07990000
  333   U(I)=U(I)+DISL2/PI2*DU(I)                                       08000000
      ENDIF                                                             08010000
C=================================                                      08020000
```

```
C=====  TENSILE-FAULT CONTRIBUTION  =====
C=========================================
      IF(DISL3.NE.F0) THEN
        DU( 1)= Q*QY                -ALP3*AI3*SDSD
        DU( 2)= Q*QX                +ALP3*XI/RD*SDSD
        DU( 3)= ET*QX+XI*QY-TT -ALP3*AI4*SDSD
        DU( 4)=-XI*Q2*Y32 -ALP3*AJ4*SDSD
        DU( 5)=-Q2/R3      -ALP3*AJ5*SDSD
        DU( 6)= Q*Q2*Y32  -ALP3*AJ6*SDSD
        DU( 7)= Q*FY -ALP3*AJ1*SDSD
        DU( 8)= Q*GY -ALP3*AJ2*SDSD
        DU( 9)=-Q*HY -ALP3*AJ3*SDSD
        DU(10)= Q*FZ +ALP3*AK3*SDSD
        DU(11)= Q*GZ +ALP3*XI*D11*SDSD
        DU(12)=-Q*HZ +ALP3*AK4*SDSD
        DO 444 I=1,12
  444   U(I)=U(I)+DISL3/PI2*DU(I)
      ENDIF
      RETURN
      END
      SUBROUTINE  UC(XI,ET,Q,Z,DISL1,DISL2,DISL3,U)
      IMPLICIT REAL*8 (A-H,O-Z)
      DIMENSION U(12),DU(12)
C
C*********************************************************************
C*****    DISPLACEMENT AND STRAIN AT DEPTH (PART-C)              *****
C*****    DUE TO BURIED FINITE FAULT IN A SEMIINFINITE MEDIUM    *****
C*********************************************************************
C
C***** INPUT
C*****   XI,ET,Q,Z    : STATION COORDINATES IN FAULT SYSTEM
C*****   DISL1-DISL3 : STRIKE-, DIP-, TENSILE-DISLOCATIONS
C***** OUTPUT
C*****   U(12) : DISPLACEMENT AND THEIR DERIVATIVES
C
      COMMON /C0/ALP1,ALP2,ALP3,ALP4,ALP5,SD,CD,SDSD,CDCD,SDCD,S2D,C2D
      COMMON /C2/XI2,ET2,Q2,R,R2,R3,R5,Y,D,TT,ALX,ALE,X11,Y11,X32,Y32,
     *           EY,EZ,FY,FZ,GY,GZ,HY,HZ
      DATA F0,F1,F2,F3,PI2/0.D0,1.D0,2.D0,3.D0,6.283185307179586D0/
C-----
      C=D+Z
      X53=(8.D0*R2+9.D0*R*XI+F3*XI2)*X11*X11*X11/R2
      Y53=(8.D0*R2+9.D0*R*ET+F3*ET2)*Y11*Y11*Y11/R2
      H=Q*CD-Z
      Z32=SD/R3-H*Y32
      Z53=F3*SD/R5-H*Y53
      Y0=Y11-XI2*Y32
      Z0=Z32-XI2*Z53
      PPY=CD/R3+Q*Y32*SD
      PPZ=SD/R3-Q*Y32*CD
      QQ=Z*Y32+Z32+Z0
      QQY=F3*C*D/R5-QQ*SD
      QQZ=F3*C*Y/R5-QQ*CD+Q*Y32
      XY=XI*Y11
      QX=Q*X11
      QY=Q*Y11
      QR=F3*Q/R5
```

```
      CQX=C*Q*X53
      CDR=(C+D)/R3
      YY0=Y/R3-Y0*CD
C=====
      DO 111  I=1,12
  111 U(I)=F0
C=================================
C=====  STRIKE-SLIP CONTRIBUTION  =====
C=================================
      IF(DISL1.NE.F0) THEN
        DU( 1)= ALP4*XY*CD            -ALP5*XI*Q*Z32
        DU( 2)= ALP4*(CD/R+F2*QY*SD) -ALP5*C*Q/R3
        DU( 3)= ALP4*QY*CD            -ALP5*(C*ET/R3-Z*Y11+XI2*Z32)
        DU( 4)= ALP4*Y0*CD                   -ALP5*Q*Z0
        DU( 5)=-ALP4*XI*(CD/R3+F2*Q*Y32*SD) +ALP5*C*XI*QR
        DU( 6)=-ALP4*XI*Q*Y32*CD             +ALP5*XI*(F3*C*ET/R5-QQ)
        DU( 7)=-ALP4*XI*PPY*CD     -ALP5*XI*QQY
        DU( 8)= ALP4*F2*(D/R3-Y0*SD)*SD-Y/R3*CD
     *                            -ALP5*(CDR*SD-ET/R3-C*Y*QR)
        DU( 9)=-ALP4*Q/R3+YY0*SD   +ALP5*(CDR*CD+C*D*QR-(Y0*CD+Q*Z0)*SD)
        DU(10)= ALP4*XI*PPZ*CD     -ALP5*XI*QQZ
        DU(11)= ALP4*F2*(Y/R3-Y0*CD)*SD+D/R3*CD -ALP5*(CDR*CD+C*D*QR)
        DU(12)=          YY0*CD    -ALP5*(CDR*SD-C*Y*QR-Y0*SDSD+Q*Z0*CD)
        DO 222 I=1,12
  222   U(I)=U(I)+DISL1/PI2*DU(I)
      ENDIF
C=================================
C=====   DIP-SLIP CONTRIBUTION   =====
C=================================
      IF(DISL2.NE.F0) THEN
        DU( 1)= ALP4*CD/R -QY*SD -ALP5*C*Q/R3
        DU( 2)= ALP4*Y*X11        -ALP5*C*ET*Q*X32
        DU( 3)=     -D*X11-XY*SD -ALP5*C*(X11-Q2*X32)
        DU( 4)=-ALP4*XI/R3*CD +ALP5*C*XI*QR +XI*Q*Y32*SD
        DU( 5)=-ALP4*Y/R3     +ALP5*C*ET*QR
        DU( 6)=    D/R3-Y0*SD +ALP5*C/R3*(F1-F3*Q2/R2)
        DU( 7)=-ALP4*ET/R3+Y0*SDSD -ALP5*(CDR*SD-C*Y*QR)
        DU( 8)= ALP4*(X11-Y*Y*X32) -ALP5*C*((D+F2*Q*CD)*X32-Y*ET*Q*X53)
        DU( 9)=  XI*PPY*SD+Y*D*X32 +ALP5*C*((Y+F2*Q*SD)*X32-Y*Q2*X53)
        DU(10)=      -Q/R3+Y0*SDCD -ALP5*(CDR*CD+C*D*QR)
        DU(11)= ALP4*Y*D*X32       -ALP5*C*((Y-F2*Q*SD)*X32+D*ET*Q*X53)
        DU(12)=-XI*PPZ*SD+X11-D*D*X32-ALP5*C*((D-F2*Q*CD)*X32-D*Q2*X53)
        DO 333 I=1,12
  333   U(I)=U(I)+DISL2/PI2*DU(I)
      ENDIF
C=================================
C=====  TENSILE-FAULT CONTRIBUTION  =====
C=================================
      IF(DISL3.NE.F0) THEN
        DU( 1)=-ALP4*(SD/R+QY*CD)    -ALP5*(Z*Y11-Q2*Z32)
        DU( 2)= ALP4*F2*XY*SD+D*X11 -ALP5*C*(X11-Q2*X32)
        DU( 3)= ALP4*(Y*X11+XY*CD)  +ALP5*Q*(C*ET*X32+XI*Z32)
        DU( 4)= ALP4*XI/R3*SD+XI*Q*Y32*CD+ALP5*XI*(F3*C*ET/R5-F2*Z32-Z0)
        DU( 5)= ALP4*F2*Y0*SD-D/R3 +ALP5*C/R3*(F1-F3*Q2/R2)
        DU( 6)=-ALP4*YY0            -ALP5*(C*ET*QR-Q*Z0)
        DU( 7)= ALP4*(Q/R3+Y0*SDCD)    +ALP5*(Z/R3*CD+C*D*QR-Q*Z0*SD)
        DU( 8)=-ALP4*F2*XI*PPY*SD-Y*D*X32
```

```
     *                    +ALP5*C*((Y+F2*Q*SD)*X32-Y*Q2*X53)
        DU( 9)=-ALP4*(XI*PPY*CD-X11+Y*Y*X32)
     *                    +ALP5*(C*((D+F2*Q*CD)*X32-Y*ET*Q*X53)+XI*QQY)
        DU(10)=  -ET/R3+Y0*CDCD -ALP5*(Z/R3*SD-C*Y*QR-Y0*SDSD+Q*Z0*CD)
        DU(11)= ALP4*F2*XI*PPZ*SD-X11+D*D*X32
     *                    -ALP5*C*((D-F2*Q*CD)*X32-D*Q2*X53)
        DU(12)= ALP4*(XI*PPZ*CD+Y*D*X32)
     *                    +ALP5*(C*((Y-F2*Q*SD)*X32+D*ET*Q*X53)+XI*QQZ)
        DO 444 I=1,12
  444   U(I)=U(I)+DISL3/PI2*DU(I)
      ENDIF
      RETURN
      END
      SUBROUTINE  DCCON0(ALPHA,DIP)
      IMPLICIT REAL*8 (A-H,O-Z)
C
C*********************************************************************
C*****   CALCULATE MEDIUM CONSTANTS AND FAULT-DIP CONSTANTS     *****
C*********************************************************************
C
C***** INPUT
C*****   ALPHA : MEDIUM CONSTANT   (LAMBDA+MYU)/(LAMBDA+2*MYU)
C*****   DIP   : DIP-ANGLE (DEGREE)
C### CAUTION ### IF COS(DIP) IS SUFFICIENTLY SMALL, IT IS SET TO ZERO
C
      COMMON /C0/ALP1,ALP2,ALP3,ALP4,ALP5,SD,CD,SDSD,CDCD,SDCD,S2D,C2D
      DATA F0,F1,F2,PI2/0.D0,1.D0,2.D0,6.283185307179586D0/
      DATA EPS/1.D-6/
C-----
      ALP1=(F1-ALPHA)/F2
      ALP2= ALPHA/F2
      ALP3=(F1-ALPHA)/ALPHA
      ALP4= F1-ALPHA
      ALP5= ALPHA
C-----
      P18=PI2/360.D0
      SD=DSIN(DIP*P18)
      CD=DCOS(DIP*P18)
      IF(DABS(CD).LT.EPS) THEN
        CD=F0
        IF(SD.GT.F0) SD= F1
        IF(SD.LT.F0) SD=-F1
      ENDIF
      SDSD=SD*SD
      CDCD=CD*CD
      SDCD=SD*CD
      S2D=F2*SDCD
      C2D=CDCD-SDSD
      RETURN
      END
      SUBROUTINE  DCCON1(X,Y,D)
      IMPLICIT REAL*8 (A-H,O-Z)
C
C*********************************************************************
C*****   CALCULATE STATION GEOMETRY CONSTANTS FOR POINT SOURCE     *****
C*********************************************************************
C
```

```
C***** INPUT
C*****   X,Y,D : STATION COORDINATES IN FAULT SYSTEM
C### CAUTION ### IF X,Y,D ARE SUFFICIENTLY SMALL, THEY ARE SET TO ZERO
C
      COMMON /C0/DUMMY(5),SD,CD
      COMMON /C1/P,Q,S,T,XY,X2,Y2,D2,R,R2,R3,R5,QR,QRX,A3,A5,B3,C3,
     *           UY,VY,WY,UZ,VZ,WZ
      DATA  F0,F1,F3,F5,EPS/0.D0,1.D0,3.D0,5.D0,1.D-6/
C-----
      IF(DABS(X).LT.EPS) X=F0
      IF(DABS(Y).LT.EPS) Y=F0
      IF(DABS(D).LT.EPS) D=F0
      P=Y*CD+D*SD
      Q=Y*SD-D*CD
      S=P*SD+Q*CD
      T=P*CD-Q*SD
      XY=X*Y
      X2=X*X
      Y2=Y*Y
      D2=D*D
      R2=X2+Y2+D2
      R =DSQRT(R2)
      IF(R.EQ.F0) RETURN
      R3=R *R2
      R5=R3*R2
      R7=R5*R2
C-----
      A3=F1-F3*X2/R2
      A5=F1-F5*X2/R2
      B3=F1-F3*Y2/R2
      C3=F1-F3*D2/R2
C-----
      QR=F3*Q/R5
      QRX=F5*QR*X/R2
C-----
      UY=SD-F5*Y*Q/R2
      UZ=CD+F5*D*Q/R2
      VY=S -F5*Y*P*Q/R2
      VZ=T +F5*D*P*Q/R2
      WY=UY+SD
      WZ=UZ+CD
      RETURN
      END
      SUBROUTINE  DCCON2(XI,ET,Q,SD,CD)
      IMPLICIT REAL*8 (A-H,O-Z)
C
C*********************************************************************
C*****   CALCULATE STATION GEOMETRY CONSTANTS FOR FINITE SOURCE   *****
C*********************************************************************
C
C***** INPUT
C*****   XI,ET,Q : STATION COORDINATES IN FAULT SYSTEM
C*****   SD,CD   : SIN, COS OF DIP-ANGLE
C
C### CAUTION ### IF XI,ET,Q ARE SUFFICIENTLY SMALL, THEY ARE SET TO ZERO
C
      COMMON /C2/XI2,ET2,Q2,R,R2,R3,R5,Y,D,TT,ALX,ALE,X11,Y11,X32,Y32,
```

```
     *            EY,EZ,FY,FZ,GY,GZ,HY,HZ                          10310000
      DATA  F0,F1,F2,EPS/0.D0,1.D0,2.D0,1.D-6/                     10320000
C-----                                                             10330000
      IF(DABS(XI).LT.EPS) XI=F0                                    10340000
      IF(DABS(ET).LT.EPS) ET=F0                                    10350000
      IF(DABS( Q).LT.EPS)  Q=F0                                    10360000
      XI2=XI*XI                                                    10370000
      ET2=ET*ET                                                    10380000
      Q2=Q*Q                                                       10390000
      R2=XI2+ET2+Q2                                                10400000
      R =DSQRT(R2)                                                 10410000
      IF(R.EQ.F0) RETURN                                           10420000
      R3=R *R2                                                     10430000
      R5=R3*R2                                                     10440000
      Y =ET*CD+Q*SD                                                10450000
      D =ET*SD-Q*CD                                                10460000
C-----                                                             10470000
      IF(Q.EQ.F0) THEN                                             10480000
        TT=F0                                                      10490000
      ELSE                                                         10500000
        TT=DATAN(XI*ET/(Q*R))                                      10510000
      ENDIF                                                        10520000
C-----                                                             10530000
      IF(XI.LT.F0 .AND. Q.EQ.F0 .AND. ET.EQ.F0) THEN               10540002
        ALX=-DLOG(R-XI)                                            10550000
        X11=F0                                                     10560000
        X32=F0                                                     10570000
      ELSE                                                         10580000
        RXI=R+XI                                                   10590002
        ALX=DLOG(RXI)                                              10600000
        X11=F1/(R*RXI)                                             10610000
        X32=(R+RXI)*X11*X11/R                                      10620002
      ENDIF                                                        10630000
C-----                                                             10640000
      IF(ET.LT.F0 .AND. Q.EQ.F0 .AND. XI.EQ.F0) THEN               10650002
        ALE=-DLOG(R-ET)                                            10660000
        Y11=F0                                                     10670000
        Y32=F0                                                     10680000
      ELSE                                                         10690000
        RET=R+ET                                                   10700002
        ALE=DLOG(RET)                                              10710000
        Y11=F1/(R*RET)                                             10720000
        Y32=(R+RET)*Y11*Y11/R                                      10730002
      ENDIF                                                        10740000
C-----                                                             10750000
      EY=SD/R-Y*Q/R3                                               10760000
      EZ=CD/R+D*Q/R3                                               10770000
      FY=D/R3+XI2*Y32*SD                                           10780000
      FZ=Y/R3+XI2*Y32*CD                                           10790000
      GY=F2*X11*SD-Y*Q*X32                                         10800000
      GZ=F2*X11*CD+D*Q*X32                                         10810000
      HY=D*Q*X32+XI*Q*Y32*SD                                       10820000
      HZ=Y*Q*X32+XI*Q*Y32*CD                                       10830000
      RETURN                                                       10840000
      END                                                          10850000
```

```
*       GIVEN

      Subroutine Given

      IMPLICIT NONE

        logical stdfil
        character*64 fill
        integer*2 vref

      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
C   no 3,4,5,6,7,
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,KSYMI
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,KSYMI
C   no 9
      REAL*4 C,B,D,DIPA
      COMMON/S10/C(1000,1000),B(1000),D(1000),DIPA(1000)
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
C   no 12,13,14,15
      INTEGER*4  NUMB1,NUMB2
      COMMON/S16/ NUMB1,NUMB2

        INTEGER*4 width,height                    ! for growing windows
        INTEGER*2 scrrect
        COMMON/S20/scrrect(4),width,height

      INTEGER*4  eof,ios,a
      REAL*4     XX22,XX32,U2,UU2,UUU2,U3,UU3,UUU3,SGX,SGXX1,SGXX2
      REAL*4     SGY,SGYY1,SGYY2,SGXY,SGXY1,SGXY2,E22,E33
      REAL*4     VOL,SHEAR
        character*1 tab
        tab=char(9)

        call clrtty
        fill = ' '
c     calls up the standard files
        if (stdfil(3,vref,' ',fill,2,'CGTXTEXT'))
     +  open (14,file = fill,status = 'old')      ! dialog.  Be sure to have on
      if (fill = ' ') then                        ! same disk or link
          return                                  ! "stdfil.sub"
          endif

        call clrtty
        fill = 'Data at given points'             ! the word between quotes is the
default name
c     calls up the standard files
        if (stdfil(2,vref,' ',fill,1,'CGTX'))
     +  open (15,file = fill,status = 'new')      ! dialog.  Be sure to have on
```

```
      if (fill = ' ') then                          ! same disk or link
          return                                    ! "stdfil.sub"
          endif


      E=E1                      ! only plot with region 1 values
      PR=PR1

      READ(14,'(a)')
      READ(14,'(a)')

c       write(15,'(a1)') '*'
        write(15,105) tab,tab,tab,tab,tab,tab,tab,tab,tab
 105    format(' X2-horiz',a1,' X3-vert ',a1,' disp-U2 ',a1,' disp-U3 '
     1,a1,' stress-22',a1,' stress-33',a1,' stress-23',a1,' strain-22'
     1,a1,' strain-33',a1,' strain-23')

      eof=-1

      DO

      READ(14,*,iostat=ios) XX22,XX32
 100  FORMAT (E11.4,a1,E11.4)

      if(ios=eof)then
        close(14)
        close(15)
       return
       endif

      CALL initil
      CALL Calcpo(XX22,XX32,U2,U3,SGXX1,SGYY1,SGXY1,0,NUMBE1)

      CALL initil
      CALL Calcpo(XX22,XX32,UU2,UU3,SGXX2,SGYY2,SGXY2,NUMB1,NUMB2)

      SGX=SGXX1+SGXX2+PXX
      SGY=SGYY1+SGYY2+PYY
      SGXY=SGXY1+SGXY2+PXY
      E22=(1.0+PR)/E*(SGX-PR*(SGX+SGY))
      E33=(1.0+PR)/E*(SGY-PR*(SGX+SGY))
      VOL=E22+E33
      SHEAR=(SGXY1+SGXY2)*(1.0+PR)/E

      UUU2=UU2+U2
      UUU3=UU3+U3

      write(15,104) XX22,tab,XX32,tab,UUU2,tab,UUU3,tab,SGX,tab,
     1SGY,tab,SGXY,tab,E22,tab,E33,tab,SHEAR

 104  format(E11.4,a1,E11.4,a1,E11.4,a1,E11.4,a1,E11.4,a1,E11.4
     1,a1,E11.4,a1,E11.4,a1,E11.4,a1,E11.4)
      REPEAT
      CLOSE(14)
      CLOSE(15)
      END
```

```
*       GRID

        subroutine grid(tty_window,plot_window,PictPaint)
C     The next section arranges data for the plot grid and either takes
C     standard data or reads from "in". At the end the corrected data
C     is written to "out".
C
*  Notes on indices from Calcul
*  NUMBS          - does not appear in calcul or, apparently, anaywhere
*  NUMBS1         - # unsplit elements in Reg1
*  NUMBS2         - # unsplit elements in Reg2
*  NUMOS          - # unsplit fixed slip elements
*  NUMBE          - floating index to calculate split elements
*  NUMBE1         - # split elements in Reg1
*  NUMBE2         - # split elements in Reg2
*  NUMBE3         - # split fixed slip elements
*  NUMB1          - dummy
*  NUMB2          - dummy
*  NUM(500)       - array containing subdivision information
*  NED            - dummy
*
*  In grid
*  NUMBER         - total number of unsplit elements
*  NUMB1          - # of split elements in Reg 1 and Reg2 together
*  NUMB2          - total number of split elements
C

      implicit none
      include demo.inc
      include quickdraw.inc

      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
      REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
      INTEGER*4 NUM
      COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
     1,BVS(500),BVN(500),DPA(500),NUM(500)
      INTEGER*4 KODES
      COMMON/S7/KODES(500)
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      REAL*4 XM,YM,A,COSBET,SINBET
      INTEGER*4 KOD
      COMMON/S9/XM(500),YM(500),A(500),COSBET(500)
     1,SINBET(500),KOD(500)
      REAL*4 C,B,D,DIPA
      COMMON/S10/C(1000,1000),B(1000),D(1000),DIPA(1000)
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
        INTEGER*4 picthdl
```

```
  COMMON/S12/picthdl(2)
 REAL*4 STARTX2,STARTX3,FINX2,FINX3,DELX2,DELX3,STMAX1
+,DELT,FRIC,SIZ,FLUID,EXAGG,FAULT
 INTEGER*4 IGRID
 COMMON/S13/STARTX2,STARTX3,FINX2,FINX3,DELX2,DELX3,STMAX1
+,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT
 LOGICAL*4   Screen,Matrix,Displacements,StressStrain
 COMMON/S14/ Screen,Matrix,Displacements,StressStrain
  INTEGER*4  NUMB1,NUMB2
 COMMON/S16/ NUMB1,NUMB2
  REAL*4       offsetx,offsety,scalex,scaley
  LOGICAL*4    in_grid
 COMMON/S17/ offsetx,offsety,scalex,scaley,in_grid

  INTEGER*4 width,height                    ! for growing windows
  INTEGER*2 scrrect
  COMMON/S20/scrrect(4),width,height

  logical stdfil
  character*64 fill
  integer*2 vref

  integer*1 tty_record(154)        ! tty window record
  integer*1 circle_record(154)     ! graphics window record

  integer*2 port(53)               ! grafport
  integer*2 windowkind             ! type of window:
  logical*1 visible                ! true when window is visible
  logical*1 hilite                 ! highlighted when true
  logical*1 goaway                 ! has a go away box when true
  logical*1 spareflag              ! reserved
  integer*4 strucrgn               ! Quickdraw region
  integer*4 contrgn                ! Quickdraw region
  integer*4 updatergn              ! Quickdraw region
  integer*4 windowdefproc          ! pointer to window definition function
  integer*4 datahandle             ! pointer for window definition function
  integer*4 titlehandle            ! pointer to title
  integer*4 titlewidth             ! width (in pixels) of title
  integer*4 controllist            ! pointer to control list for Control Mgr
  integer*4 nextwindow             ! pointer to next window in window list
  integer*4 windowpic              ! pointer to Quickdraw picture of contents
  integer*4 refcon                 ! reference value field
  integer*4 PictPaint
  equivalence (tty_record(1),port)
  equivalence (tty_record(104),windowkind)
  equivalence (tty_record(109),visible)
  equivalence (tty_record(110),hilite)
  equivalence (tty_record(111),goaway)
  equivalence (tty_record(112),spareflag)
  equivalence (tty_record(113),strucrgn)
  equivalence (tty_record(114),contrgn)
  equivalence (tty_record(121),updatergn)
  equivalence (tty_record(125),windowdefproc)
  equivalence (tty_record(129),datahandle)
  equivalence (tty_record(133),titlehandle)
  equivalence (tty_record(137),titlewidth)
  equivalence (tty_record(139),controllist)
```

```
      equivalence (tty_record(143),nextwindow)
      equivalence (tty_record(147),windowpic)
      equivalence (tty_record(151),refcon)

      character*256 str255            ! function to create a Pascal LSTRING
      integer*4 window                ! general purpose pointer
      integer*4 size,w,h              ! for growing windows
      integer*2 rect(4)               ! rectangle coordinates
      integer mouseloc                ! mouse location from FINDWINDOW:
c                                     !   0 = none of the following
c                                     !   1 = in the menu bar
c                                     !   2 = in system window
c                                     !   3 = in content region
c                                     !   4 = in drag region
c                                     !   5 = in grow region
c                                     !   6 = in go away region

*

      INTEGER*2 scrrect2(4)


      integer*4 ixx,iyy,ixtext,iytext
      integer*4 ix1,iy1,ix2,iy2,ix3,iy3,ix4,iy4,idelx,idely
      integer*4 idelxold,idelyold,idelxx,idelyy,jin
      integer*4 tty_window            ! pointer to the tty window
      integer*4 plot_window           ! pointer to the graphics window

      integer*4 poly
      integer*1 pat(8)
      integer*1 white(8)
      integer*1 black(8)
      integer*4 toolbx                ! the tool box interface

     INTEGER*4 NUMBER,I,ID,IGRIDA,IGRIDO,IDISP,IBASE,IROSE,M
     INTEGER*4 IFLAG,ISET,INTE,INED,IND
     INTEGER*4  i,irosette,I2,II2,I3,II3,III3
     INTEGER*4  iout,percent
     REAL*4    X2,X3,XY,XZ
     REAL*4    STMAX,SCALE
     REAL*4    xcent,ycent,cen2,cen3,CEN2,CEN3,X2OR,X3OR
     REAL*4    U2,UU2,UUU2,U3,UU3,UUU3,UUX2,UUX3
     REAL*4    UX2,UX3
     REAL*4    XX22,XX32,XX24,XX34
     REAL*4    XX2,XX3
     REAL*4    SGX,SGY,SGXY,E22,E33,VOL,VOLGD,VAL,VALFR,VALFL
     REAL*4    DIFF,SHEAR,SHEARGD,CURL,SIGSHEAR,SIGNOR
     REAL*4    SIGSHEARF,SIGNORF
     REAL*4    SGXX1,SGYY1,SGXY1,SGXX2,SGYY2,SGXY2
     REAL*4    XE22,XE22B,XE23,XE32,XE33,XE33B
     REAL*4    rad,PHI,COST,SINT,ERAD1,ERAD2,ERAD3,ERADOLD
     REAL*4    U2A,U3A,ANGBETA,INDFRIC
     REAL*4    APHI,ABETA,ALEFT,ARIGHT,SFX,SFY,SFXY
     REAL*4    SIZE1,ANGLE
```

```
      DIMENSION X2(4),X3(4),XY(4),XZ(4)
      DIMENSION U2A(1000),U3A(1000)

      character*1 tab
      INTEGER*4  eof,ios,Plane_stress

      tab=char(9)


c      DATA scrrect /0,0,480,640/  !MacII= 480, 640 SE=342,512
c      DATA scrrect2 /0,0,4800,6400/  !MacII= 480, 640 SE=342,512
        scrrect2(1)=scrrect(1)
        scrrect2(2)=scrrect(2)
        scrrect2(3)=scrrect(3)
        scrrect2(4)=scrrect(4)
c******
      xcent=   width/2  !          for MacII screen    320.0
      ycent=   height/2  !                              250.0

      Plane_stress = 1  ! to change to plane stress this should be 1
                   ! otherwise 0.  Change nothing else and recompile

      NUMBER=NUMBS1+NUMBS2+NUMOS          !total unsplit elements

      data white   /b'00000000',
     +              b'00000000',
     +              b'00000000',
     +              b'00000000',
     +              b'00000000',
     +              b'00000000',
     +              b'00000000',
     +              b'00000000'/

      data black   /b'11111111',
     +              b'11111111',
     +              b'11111111',
     +              b'11111111',
     +              b'11111111',
     +              b'11111111',
     +              b'11111111',
     +              b'11111111'/

C
          call toolbx(BRINGTOFRONT,tty_window)
          call toolbx(SETPORT,tty_window)
          call clrtty

  601 CONTINUE
      PRINT*," "
      PRINT*," "
      PRINT*," "
      PRINT*,"Type 5 for example grid "
      PRINT*,"     1 for last file or old file (labelled gridout)"
      PRINT*,"     0 for file menu "
      READ*,ID
      IF(ID.EQ.5) THEN
```

```
      STARTX2 = -5.0
      STARTX3 = -5.0
      FINX2   =  5.0
      FINX3   =  5.0
      DELX2   =  1.0
      DELX3   =  1.0

      STMAX1  =  5.0
      DELT    =  0.1
      FRIC    =  0.0
      FLUID   =  0.0
      SIZ     = 40.0
      EXAGG   =  1.0
      FAULT   =  0.0
      IGRID   =  0

      END IF

      iout=0

      OPEN(14,ACCESS="SEQUENTIAL",STATUS="NEW",FILE="Coulomb")    !!!!!!!
      REWIND 14                                                   !!!!!!!
        write(14,905) tab,tab,tab,tab,tab,tab,tab,tab
     1              ,tab,tab,tab,tab,tab,tab,tab
!!!!!!!
 905    format('X2-horiz',a1,'X3-vert',a1,'coulomb',a1,
     1         'sigx', a1,'sigfx',a1,'sigy',    a1,
     2         'sigfy',a1,'sigxy',a1,'sigfxy',  a1,
     3         'sigs', a1,'sign', a1,'phi-beta',a1,
     4         'phi+beta',a1,'prin1',a1,'prin2',a1,'prin3')

      IF(Displacements)then
      OPEN(12,ACCESS="SEQUENTIAL",STATUS="UNKNOWN",FILE="Displacements")
      REWIND 12

        write(12,105) tab,tab,tab
 105    format('X2-horiz',a1,'X3-vert',a1,'disp-U2',a1,'disp-U3')

      ENDIF

      IF(StressStrain)then
      OPEN(11,ACCESS="SEQUENTIAL",STATUS="UNKNOWN",FILE="stressstrain")
      REWIND 11
        write(11,106) tab,tab,tab,tab,tab,tab,tab
 106  format('X2-horiz',a1,'X3-vert ',a1,'stress-22',a1,'stress-33'
     1,a1,'stress-23',a1,'strain-22',a1,'strain-33',a1,'strain-23')
      ENDIF

       eof=-1

      IF(ID.EQ.1) THEN
      OPEN(7,ACCESS="SEQUENTIAL",STATUS="UNKNOWN",FILE="gridout")
      REWIND 7
      READ(7,9101,iostat=ios) STARTX2,STARTX3,FINX2,FINX3,DELX2
     +            ,DELX3,STMAX1,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT

 9101 FORMAT(46X,G16.7,/,46X,G16.7,/,46X,G16.7,/,46X,G16.7,/,46X,G16.7,/,
```

```
     +46X,G16.7,/,46X,2G16.7,F5.2/,46X,G16.7,F5.2/,46X,I12,/,46X,G16.7
     +,F5.2)
      if(ios.eq.eof)then
      PRINT*,'Bad file - try again'
      return
      endif
      END IF

      IF(ID.EQ.0)THEN
        call clrtty
        fill = ' '
c     calls up the standard files
        if (stdfil(3,vref,' ',fill,1,'TEXT'))
     +  open (13,file = fill,status = 'old')     ! dialog.  Be sure to have on
      if (fill = ' ') then                       ! same disk or link
          return                                 ! "stdfil.sub"
          endif

      REWIND 13
      READ(13,9101,iostat=ios) STARTX2,STARTX3,FINX2,FINX3,DELX2
     +           ,DELX3,STMAX1,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT
      if(ios.eq.eof)return
      call toolbx(MOVETO,0,40)
        END IF

      If(Plane_stress.eq.0) then
      Print*,"Grid is set for Plane Strain (the usual condition).
     + To use plane stress"
      Print*,"for Coulomb and Slip lines make Plane_stress = 1 in
     + the Grid subroutine and recompile."
      else
      Print*,"Grid is set for Plane Stress. This modifies Coulomb
     + and slip line facilities."
      Print*,"When this is used the appropriate different modulii
     + (see p20 Crouch & Starfield)"
      Print*,"should also be used."
      Print*,"To remove this option make Plane_stress = 0 in the
     + Grid subroutine and recompile."
      endif

      Print*," "
      Print*," "

   99 WRITE(*,9100)STARTX2,STARTX3,FINX2,FINX3,DELX2
     +,DELX3,STMAX1,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT

 9100 FORMAT(" 1  ----------------------------  Start-x = ",G16.7
     1    ,/," 2  ----------------------------  Start-y = ",G16.7
     1    ,/," 3  --------------------------   Finish-x = ",G16.7
     1    ,/," 4  --------------------------   Finish-y = ",G16.7
     1    ,/," 5  ------------------------  x-increment = ",G16.7
     1    ,/," 6  ------------------------  y-increment = ",G16.7
     1    ,/," 7  Max strain, shade increment, friction = ",2G16.7,F5.2
     1    ,/," 8  Plot size factor,  Skempton's coeff B = ",G16.7,F5.2
     1    ,/," 9  ------  Existence of grid and shading = ",I12
     1    ,/," 10 Vert Exg,1=Pij used for orientas.only = ",G16.7,F5.2
     1    ,/)
```

```
PRINT*,"Type index of number to be changed or 0 to continue"
READ*,I

IF(I.EQ.0) GOTO 102

IF(I.EQ.1) THEN
PRINT*,"New start-x"
READ*,STARTX2
END IF

IF(I.EQ.2) THEN
PRINT*,"New start-y"
READ*,STARTX3
END IF

IF(I.EQ.3) THEN
PRINT*,"New finish-x"
READ*,FINX2
END IF

IF(I.EQ.4) THEN
PRINT*,"New finish-y"
READ*,FINX3
END IF

IF(I.EQ.5) THEN
PRINT*,"New x-increment"
READ*,DELX2
END IF

IF(I.EQ.6) THEN
PRINT*,"New y-increment"
READ*,DELX3
END IF

IF(I.EQ.7) THEN
PRINT*,"New max strains, shade interval, friction angle"
PRINT*,""
PRINT*,"Small max strain value suppresses plotting where"
PRINT*,"strains exceed the those given by multiplying or"
PRINT*,"dividing by the value. IF A NEGATIVE VALUE IS USED"
PRINT*,"REGION 2 IS PLOTTED"
PRINT*,""
PRINT*,"The second number is the increment for shading"
PRINT*,"or other size scaling"
PRINT*,"The third number is the value of friction where "
PRINT*,"appropriate. Make value negative to allow left- "
PRINT*,"and right-lateral slip-lines to be plotted separately"
PRINT*,"The fourth number is the value of Skempton's "
PRINT*,"coefficient of pore fluid pressure "
PRINT*,""
PRINT*,"(separate values by commas)"
READ*,STMAX1,DELT,FRIC
END IF
```

```
      IF(I.EQ.8) THEN
      PRINT*,"New plot size multiplier, Skempton's coefficient B"
      READ*,SIZ,FLUID
      END IF

      IF(I.EQ.9) THEN
      PRINT*,"Select number."
      PRINT*,"0 for undistorted grid and element locations"
      PRINT*,"1 for grid only."
      PRINT*,"2 for grid and shaded shear."
      PRINT*,"3 for grid and numbered shear."
      PRINT*,"4 for grid and shaded dilatation."
      PRINT*,"5 for grid and numbered dilatation."
      PRINT*,"6 for displacement lines."
      PRINT*,"7 for displacement lines with numbers."
      PRINT*,"8 for shaded Coulomb criteria"
      PRINT*,""
      PRINT*,"DOUBLE DIGITS JUST GIVE SIGN OF NUMBERS"
      PRINT*,"    ( e.g.   33 )"
      PRINT*,"TRIPLE DIGITS GIVE SLIP LINES"
      PRINT*,"    ( e.g. -111 )"
      PRINT*,"NEGATIVE VALUES REMOVE GRID"
      READ*,IGRID
      END IF

      IF(I.EQ.10) THEN
      PRINT*,"New Vertical Exaggeration,1=Pij used for orientas.only"
      READ*,EXAGG,FAULT
      END IF

      GO TO 99
  102 CONTINUE

      CLOSE (7)
      CLOSE (13)
      OPEN(8,ACCESS="SEQUENTIAL",STATUS="UNKNOWN",FILE="gridout")
      WRITE(8,9100)STARTX2,STARTX3,FINX2,FINX3,DELX2
     +,DELX3,STMAX1,DELT,FRIC,SIZ,FLUID,IGRID,EXAGG,FAULT
      CLOSE(8)

      IF(IGRID.EQ.0)then          !enable mouse get co-ords routine
      in_grid=.true.
      else
      in_grid=.false.
      endif

        ISET= 0
        IF(STMAX1.LE.0.0)then
        STMAX1=-STMAX1
        ISET=1
        ENDIF

************ Start of section concerns plotting slip lines ***************

        IF(IGRID.GE.100.OR.IGRID.LE.-100) THEN
        IF(FRIC.LT.0.0)THEN
```

```
        PRINT*,"TYPE 1 for right lateral set, 2 for left lateral set"
        PRINT*,"TYPE 0 for both"
        READ *,INDFRIC
        ENDIF
        ENDIF

        IF(FRIC.LT.0.0)  FRIC = -FRIC
        ANGBETA = PI/2.0 - 0.5*ATAN(1.0/FRIC)

************ End of section concerns plotting slip lines ***************

C  ----------------------------------------------------------------
C
C
C  ----------------------------- 13 ---------------------------------
C     Compute displacements and stresses at specified points in body.
C     This has a number of sub-parts
C
C                              The do loops for the raster start here.
C    Note that the raster program considers X2 and X3 co-ordinate
C    directions and  no X1. In the 3-dimensional program this lies
C    along fault strike. Thus from the earlier part of this program
C    X translates to X2 and Y translates to X3. Variations on these
C    create different variables. For example E22 is strain in the
C    original X direction and E33 is strain in the original Y direc
C    -tion.
C    The final plot puts X (X2) accross and Y (X3) down. In other
C    words we measure from the Earth's surface positive downwards.
C    In referring to positions we assume this orintation of axes.
C

       call toolbx(SETPORT,plot_window)
       call toolbx(CLIPRECT,scrrect2)
       call toolbx(ERASERECT,scrrect2)
       picthdl(1) = toolbx(OPENPICTURE,scrrect2)        ! set-up for pict format
      call toolbx(CLOSEPICTURE)
      call toolbx(DRAWPICTURE,picthdl(1),scrrect)
      call toolbx(SETWINDOWPIC,plot_window,picthdl(1))  ! to have the screen
refreshed

      I3=(FINX3-STARTX3)/DELX3 +1
      CEN3=SIZ*EXAGG*(FINX3+STARTX3)/2.0
      I2=(FINX2-STARTX2)/DELX2+3
      CEN2=SIZ*(FINX2+STARTX2)/2.0

      offsetx = CEN2-xcent     ! information for picking elements
      offsety = CEN3-ycent     ! from screen
      scalex= 1.0/SIZ/EXAGG
      scaley= 1.0/SIZ


       call toolbx(SETPORT,plot_window)
       call toolbx(CLIPRECT,scrrect2)
       call toolbx(ERASERECT,scrrect2)
C         call toolbx(BACKCOLOR,409)
C         call toolbx(FORECOLOR,205)
```

```
      if(PictPaint.EQ.1)then
      picthdl(1) = toolbx(OPENPICTURE,scrrect2)        ! set-up for pict format
      else
      call toolbx(BRINGTOFRONT,plot_window)            ! set-up for screen plot
      endif
      call toolbx(TEXTFONT,4)            ! monaco
      call toolbx(TEXTSIZE,9)            ! 9 point
     X2(1)=0.0
     X2(2)=0.0
     X2(3)=0.0
     X2(4)=0.0
     X3(1)=0.0
     X3(2)=0.0
     X3(3)=0.0
     X3(4)=0.0
     NUMB1=NUMBE1+NUMBE2
     NUMB2=NUMBE1+NUMBE2+NUMBE3
     E=E1                        ! only plot with region 1 values
     PR=PR1
       IF(ISET.EQ.1)then        !change to region2 values
       E=E2
       PR=PR2
       ENDIF
     IDISP=0
     UUU2=0.0
     UUU3=0.0

     DO 1266 II2=1,I2
     U2A(II2)=0.0
     U3A(II2)=0.0
1266 CONTINUE
     IF(IGRID.EQ.0) GOTO 676

c  next segment deals with displacement lines

     IF(IGRID.EQ.6) GOTO 544
     IF(IGRID.EQ.7) GOTO 544
     GO TO 545
544  CONTINUE
     call toolbx(BRINGTOFRONT,tty_window)
     call toolbx(SETPORT,tty_window)
     PRINT*,'Supply X and Y of origin 999,0 for none'
     READ*,X2OR,X3OR
     PRINT*,'Supply scaling for vectors'
     READ*,SCALE
      call toolbx(BRINGTOFRONT,plot_window)
      call toolbx(SETPORT,plot_window)
     IF(X2OR.EQ.999) GOTO 545
     ixx=INT((X2OR*SIZ)-CEN2+xcent-2.0)
     iyy=INT((X3OR*SIZ*EXAGG)-CEN3+ycent+3.0)
     call toolbx(MOVETO,ixx,iyy)
     CALL initil
     IF(ISET.EQ.0)then
     CALL Calcpo(X2OR,X3OR,U2,U3,SGXX1,SGYY1,SGXY1,0,NUMBE1)    ! reg1 sum
     ELSE
     CALL Calcpo(X2OR,X3OR,U2,U3,SGXX1,SGYY1,SGXY1,
    +NUMBE1,NUMB1)                                              ! reg2 sum
```

```
      ENDIF
      CALL initil
      IF(ISET.EQ.0)then
      CALL Calcpo(X2OR,X3OR,UU2,UU3,SGXX2,SGYY2,SGXY2,
     +NUMB1,NUMB2)                                          ! fixed elements
sum
      ENDIF
      UUU2=U2+UU2
      UUU3=U3+UU3
      PRINT*,'o'

c     ************************************************************

 545  CONTINUE

      DO 1100 III3=1,I3

      DO 1050 II2=1,I2
      if(PictPaint.EQ.1)then              ! set for pict format
      IF(iout.NE.III3) THEN
      call toolbx(BRINGTOFRONT,tty_window)
      call toolbx(SETPORT,tty_window)
      call clrtty
      call toolbx(TEXTSIZE,56)            ! 56 point
      percent=(iout*100)/I3
      PRINT*,"     "
      PRINT*," ",percent," percent"
      PRINT*,"  complete"
       call toolbx(TEXTSIZE,9)            ! 9 point
       call toolbx(SETPORT,plot_window)
      ENDIF
      iout=III3
      endif

      II3=I3-III3+1
      XX3=STARTX3+(II3-1)*DELX3
      XX2=STARTX2+DELX2*(II2-2)
C  The raster is created by holding four points in store. The points
C  correspond to an initially undeformed square box and ar:-
C  1- top left, 2- top right, 3- bottom left, 4- bottom right.
C  To keep all of these values correct and maintain a simple algor-
C  ithm, the program goes outside the plotted area by one box unit.
C  The program is always calculating a pair of points ahead of those
C  it is plotting.

      UUX2=UX2
      UUX3=UX3
      X2(1)=X2(2)
      X3(1)=X3(2)
      X2(3)=X2(4)
      X3(3)=X3(4)
      XX22=XX2+DELX2
      XX32=XX3
      XX24=XX2+DELX2
      XX34=XX3+DELX3

C     Puts VOL and SHEAR equal to values calculated on the last loop
```

```
C     We plot one increment behind the one we calculate
C     This means strain correspond to the value at the top left
C     corner of each box.
C     The program calculates strains in two ways. One is from the
C     stresses coming from calcpo and the second is numerically
C     from the deformed grid. As the program is set-up the former
C     gives the value at the top left corner of the box and the
C     latter calculates it from the left and bottom side lengths
C     and the angles between them. The numerical calculation is
C     preferred for deciding when the grid is too distorted to plot.

      SGX=SGXX1+SGXX2+PXX
      SGY=SGYY1+SGYY2+PYY
      SGXY=SGXY1+SGXY2+PXY
      E22=(1.0+PR)/E*(SGX-PR*(SGX+SGY))
      E33=(1.0+PR)/E*(SGY-PR*(SGX+SGY))
      VOL=E22+E33

      SHEAR=(SGXY)*(1.0+PR)/E

C If not commented out, the following four lines replace shading values
C with numerical values from the deformed grid rather than values from
C calcpo. THIS DOES NOT INCLUDE PRE-EXISTING STRESSES

c        E22= XE22
c        E33= XE33
c        VOL= VOLGD
c        SHEAR= SHEARGD

      IF(Displacements)then
      IF(XX2.GE.(STARTX2-1.0).and.XX2.LE.(FINX2-1.0).and.
     1XX3.GE.STARTX3.and.XX3.LE.FINX3)then
      WRITE(12,103) XX2,tab,XX3,tab,UUX2,tab,UUX3
103   format(G16.7,a1,G16.7,a1,G16.7,a1,G16.7)
      endif
      endif

      IF(StressStrain)then
      IF(XX2.GE.(STARTX2-1.0).and.XX2.LE.(FINX2-1.0).and.
     1XX3.GE.STARTX3.and.XX3.LE.FINX3)then
      write(11,104) XX2,tab,XX3,tab,SGX,tab,
     1SGY,tab,SGXY,tab,E22,tab,E33,tab,SHEAR
 104  format(G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,G16.7
     1,a1,G16.7,a1,G16.7)
      endif
      endif

      X2(4)=U2A(II2)+XX24
      X3(4)=U3A(II2)+XX34

      CALL initil
      IF(ISET.EQ.0)then
      CALL Calcpo(XX22,XX32,U2,U3,SGXX1,SGYY1,SGXY1,0,NUMBE1)          ! reg1 sum
      ELSE
      CALL Calcpo(XX22,XX32,U2,U3,SGXX1,SGYY1,SGXY1,                   ! reg2 sum
     +NUMBE1,NUMB1)
      ENDIF
```

```
      CALL initil
      IF(ISET.EQ.0)then
      CALL Calcpo(XX22,XX32,UU2,UU3,SGXX2,SGYY2,SGXY2,NUMB1,NUMB2)       ! fixed
element sum
      ENDIF

cccccccc        UU2=0.0          These stop preset faults plotting
cccccccc        UU3=0.0
cccccccc        SGXX2=0.0
cccccccc        SGYY2=0.0
cccccccc        SGXY2=0.0

      UX2=(U2+UU2)-UUU2
      UX3=(U3+UU3)-UUU3
      X2(2)=U2+UU2+XX22
      X3(2)=U3+UU3+XX32

      U2A(II2)=(U2+UU2)
      U3A(II2)=(U3+UU3)

C     This is the numerical routine
      CALL STRAIN(X2,X3,DELX2,DELX3,XE22,XE22B,XE23,XE32,XE33,XE33B
     +,VOLGD,SHEARGD,CURL)

C   The shading needs an array that goes round the box in
C   clockwise order. This new array of four points is created from the
C   old array and scaled at the same time.

      XY(1)=X2(1)*SIZ
      XZ(1)=X3(1)*SIZ*EXAGG
      XY(2)=X2(2)*SIZ
      XZ(2)=X3(2)*SIZ*EXAGG
      XY(3)=X2(4)*SIZ
      XZ(3)=X3(4)*SIZ*EXAGG
      XY(4)=X2(3)*SIZ
      XZ(4)=X3(3)*SIZ*EXAGG

      IGRIDA=IGRID
      IGRIDO=1
      IBASE=0                    !DETERMINES BASELINE OF SHADING
      IDISP=0
      IROSE=0
      IFLAG=0
      ISIGN=0

      IF(XX2.LT.STARTX2)    GO TO 1150
      IF(XX3.GT.FINX3)      GO TO 1150    !+!
      IF(XX2.GE.FINX2)      GO TO 1150

C   The next block of statements are concerned with shading boxes
C   for the Mac display.

      IF(IGRIDA.EQ.6) GO TO 1111
      IF(IGRIDA.EQ.7) GO TO 1111

      IF(IGRIDA.LT.0) THEN
      IGRIDA=-IGRID
```

```
      IGRIDO=2
      ENDIF
      IF(IGRIDA.LE.100)THEN
      IF(IGRIDA.GE.10)THEN
      IGRIDA=IGRIDA/11
      ISIGN=1
      ENDIF
      ENDIF
      IF(IGRIDA.GE.100) THEN
      IGRIDA=IGRIDA/111
      IROSE=1
      ENDIF


      IF(IGRIDA.EQ.3) THEN
      IGRIDA=2
      IFLAG=1
      ENDIF

      IF(IGRIDA.EQ.5) THEN
      IGRIDA=4
      IFLAG=1
      ENDIF

      IF (IGRIDA.EQ.2) THEN
      DIFF=(E22-E33)
      VAL=SQRT(SHEAR*SHEAR+DIFF*DIFF/4)
      ENDIF

      IF(IGRIDA.EQ.4) THEN
      IBASE=1
      VAL=VOL
      ENDIF

****** Start of section concerning shading the coulomb criteria *********

      IF (IGRIDA.EQ.8) THEN
      IBASE=1
        PHI = 0.5*ATAN((2*SGXY)/(SGX-SGY)) !calculate angle of principal axes
        COST=COS(PHI)
        SINT=SIN(PHI)
      ERAD1=(SGX*COST*COST+SGY*SINT*SINT+2.0*SGXY*COST*SINT) !principal stress 1
        COST=COS(PHI+ PI/2.0)
        SINT=SIN(PHI+ PI/2.0)
      ERAD2=(SGX*COST*COST+SGY*SINT*SINT+2.0*SGXY*COST*SINT) !principal stress 2
        IF(ERAD2.GE.ERAD1) PHI=PHI+PI/2.0   !set phi to indicate max principal
stress

      If(Plane_stress.eq.0) then
      ERAD3 = PR*(ERAD1+ERAD2)            !plane strain condx
      else
      ERAD3 = 0.0                         !plane stress condx
      endif


        COST=COS(PHI-ANGBETA-PI/2.0)
        SINT=SIN(PHI-ANGBETA-PI/2.0)
```

```
      SFX=SGX-FAULT*PXX
      SFY=SGY-FAULT*PYY
      SFXY=SGXY-FAULT*PXX

      SIGNOR = SFX*COST*COST + 2.0*SFXY*SINT*COST + SFY*SINT*SINT
      SIGSHEAR=(SFY-SFX)*SINT*COST + SFXY*(COST*COST-SINT*SINT)

      If(Plane_stress.eq.0) then
      VAL= -(SIGSHEAR)+FRIC*(SIGNOR - FLUID*(1+PR)*(SFX+SFY)/3.0)
                                  !plane strain condx
      else
      VAL= -(SIGSHEAR)+FRIC*(SIGNOR - FLUID*(SFX+SFY)/3.0)
                                  !plane stress condx
      endif

      APHI=PHI*180./PI
      ABETA=ANGBETA*180./PI
      ALEFT=APHI-ABETA
      ARIGHT=APHI+ABETA

      WRITE(14,903) XX2,tab,XX3,tab,VAL,tab,SGX,tab,SFX,tab,
     1                  SGY,tab,SFY,tab,SGXY,tab,SFXY,tab,
     2                  SIGSHEAR,tab,SIGNOR,tab,ALEFT,tab,
     3                ARIGHT,tab,ERAD1,tab,ERAD2,tab,ERAD3
 903   format(G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,
     1        G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,
     2        G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,
     3        G16.7,a1,G16.7)

       ENDIF

****** End of section concerning shading the coulomb criteria *********

      CALL GETSHADE(VAL,DELT,IBASE,INTE,pat)

 1150 CONTINUE

      IF(XX2.LT.STARTX2)          GO TO 1111
      IF(XX2.GE.FINX2)            GO TO 1111
      IF(XX3.GE.FINX3)            GO TO 1111
      IF(ABS(XE22).GT.STMAX1)    GO TO 1111
      IF(ABS(XE33).GT.STMAX1)    GO TO 1111
      IF(ABS(XE22B).GT.STMAX1)   GO TO 1111
      IF(ABS(XE33B).GT.STMAX1)   GO TO 1111
      IF(ABS(VOLGD).GT.STMAX1)   GO TO 1111
      IF(ABS(SHEARGD).GT.STMAX1) GO TO 1111


       poly= toolbx(OPENPOLY)


       ixx=XY(4)-CEN2+xcent
       iyy=XZ(4)-CEN3+ycent
       call toolbx (MOVETO,ixx,iyy)
```

```
      ixx=XY(3)-CEN2+xcent
      iyy=XZ(3)-CEN3+ycent
      call toolbx (LINETO,ixx,iyy)

      ixx=XY(2)-CEN2+xcent
      iyy=XZ(2)-CEN3+ycent
      call toolbx (LINETO,ixx,iyy)

      ixx=XY(1)-CEN2+xcent
      iyy=XZ(1)-CEN3+ycent
      call toolbx (LINETO,ixx,iyy)

      ixx=XY(4)-CEN2+xcent
      iyy=XZ(4)-CEN3+ycent
      call toolbx (LINETO,ixx,iyy)


         call toolbx (CLOSEPOLY)
         if(IFLAG.EQ.1.or.IGRIDA.EQ.1)go to 3210
         call toolbx(PENPAT,pat)
         call toolbx (PAINTPOLY,poly)
3210     continue
         if(IGRIDO.EQ.1)then
         call toolbx(PENPAT,black)
         call toolbx (FRAMEPOLY,poly)
         endif

1111 CONTINUE
         call toolbx(PENNORMAL)
C    The next block of statements concern line plotting.


      INED=0
       ix1=XY(1)-CEN2+xcent
       iy1=XZ(1)-CEN3+ycent
       ix2=XY(2)-CEN2+xcent
       iy2=XZ(2)-CEN3+ycent
       ix3=XY(3)-CEN2+xcent
       iy3=XZ(3)-CEN3+ycent
       ix4=XY(4)-CEN2+xcent
       iy4=XZ(4)-CEN3+ycent


       ixx=ix1+(ix3-ix1)/2 - 8
       iyy=iy1+(iy3-iy1)/2 + 5

     IF(II2.GE.2)                    INED= IGRIDO
     IF(II2.GT.(I2-1))               INED=0
     IF(II3.GE.(I3))                 INED=0
     IF(ABS(XE22).GT.STMAX1)        INED=0
     IF(ABS(XE33).GT.STMAX1)        INED=0
     IF(ABS(XE22B).GT.STMAX1)       INED=0
```

```
      IF(ABS(XE33B).GT.STMAX1)      INED=0
      IF(ABS(VOLGD).GT.STMAX1)      INED=0
      IF(ABS(SHEARGD).GT.STMAX1)    INED=0

        call toolbx(MOVETO,ixx,iyy)
        IF(IFLAG.EQ.1)THEN
        IF(INED.EQ.IGRIDO)THEN
        IF(XX2.NE.FINX2)THEN
        IF(ISIGN.EQ.0)THEN
        INT=IABS(INTE)
        PRINT*,INT
        ENDIF
        IF(ISIGN.EQ.1)THEN
        IF(INTE.GE.1)THEN
        PRINT*," +"
        ENDIF
        IF(INTE.LE.-1)THEN
        PRINT*," -"
        ENDIF
        ENDIF
        ENDIF
        ENDIF
        ENDIF

        IF(IGRIDA.EQ.7) THEN
        IGRIDA=6
        IDISP=1
        ENDIF

        IF(IGRIDA.EQ.6) THEN
           IF(INED.EQ.IGRIDO) THEN
             ix1=INT(((XX2+(UUX2*SCALE))*SIZ)-CEN2+xcent)
             iy1=INT(((XX3+(UUX3*SCALE))*SIZ*EXAGG)-CEN3+ycent)
             call toolbx(MOVETO,ix1,iy1)
             rad= SQRT((UUX2*UUX2)+(UUX3*UUX3))
             jin= INT(rad/DELT)
             ixx=INT((XX2*SIZ)-CEN2+xcent)
             iyy=INT((XX3*SIZ*EXAGG)-CEN3+ycent)
             ixx=ixx-8
             call toolbx(MOVETO,ixx,iyy)

                  IF(IDISP.EQ.1) THEN
                      If(jin.le.99)then
                      PRINT*,jin
                      endif
                   ENDIF

                  ixx=ixx+8
         call toolbx(MOVETO,ixx,iyy)
         call toolbx(LINETO,ix1,iy1)

            ENDIF
         go to 1166
            ENDIF
************ Start of section concerns plotting slip lines ***************
```

```
 IF(IROSE.EQ.1)THEN
IF(XX2.GE.STARTX2)            IND=1
IF(XX2.GE.FINX2)              IND=0
IF(XX3.GT.FINX3)              IND=0
IF(ABS(XE22).GT.STMAX1)      IND=0
IF(ABS(XE33).GT.STMAX1)      IND=0
IF(ABS(XE22B).GT.STMAX1)     IND=0
IF(ABS(XE33B).GT.STMAX1)     IND=0
IF(ABS(VOLGD).GT.STMAX1)     IND=0
IF(ABS(SHEARGD).GT.STMAX1)   IND=0


  PHI = 0.5*ATAN((2*SGXY)/(SGX-SGY)) !calculate angle of principal axes
  COST=COS(PHI)
  SINT=SIN(PHI)
ERAD1=(SGX*COST*COST+SGY*SINT*SINT+2.0*SGXY*COST*SINT) !principal stress 1
  COST=COS(PHI+ PI/2.0)
  SINT=SIN(PHI+ PI/2.0)
ERAD2=(SGX*COST*COST+SGY*SINT*SINT+2.0*SGXY*COST*SINT) !principal stress 2
  IF(ERAD2.GE.ERAD1) PHI=PHI+PI/2.0   !set phi to indicate max principal
stress
ERAD3 = PR*(ERAD1+ERAD2)

  COST=COS(PHI-ANGBETA-PI/2.0)
  SINT=SIN(PHI-ANGBETA-PI/2.0)


If(Plane_stress.eq.0) then                  !plane strain condx
  IF(ERAD3.GE.ERAD2.AND.ERAD3.GT.ERAD1) GO TO 1984
  IF(ERAD3.LE.ERAD2.AND.ERAD3.LT.ERAD1) GO TO 1984
endif
  IF(IND.NE.1) GO TO 1984

  IF(INDFRIC.NE.2) THEN                 ! this is a right lateral set
COST=COS(PHI+ANGBETA)
SINT=SIN(PHI+ANGBETA)
 idelx= INT(DELT*30.0*COST)
 idely= INT(DELT*30.0*SINT)
idelxx=ix1+idelx
idelyy=iy1+idely
call toolbx(MOVETO,idelxx,idelyy)
idelxx=ix1-idelx
idelyy=iy1-idely
call toolbx(LINETO,idelxx,idelyy)
  ENDIF

  IF(INDFRIC.NE.1) THEN                 ! this is a left lateral set
COST=COS(PHI-ANGBETA)
SINT=SIN(PHI-ANGBETA)
 idelx= INT(DELT*30.0*COST)
 idely= INT(DELT*30.0*SINT)
idelxx=ix1+idelx
idelyy=iy1+idely
call toolbx(MOVETO,idelxx,idelyy)
idelxx=ix1-idelx
idelyy=iy1-idely
call toolbx(LINETO,idelxx,idelyy)
```

```
        ENDIF
 1984 CONTINUE

************ End of section concerns plotting slip lines ***************

 1166 continue

      ENDIF
 1050 CONTINUE
 1100 CONTINUE
      GOTO 727



 676  CONTINUE
c                        ************ NEW CODE HERE *************

      XX2=STARTX2
      XX3=STARTX3
      DO 725 WHILE (XX3.LE.FINX3)
      ixx = (XX2*SIZ)-CEN2+xcent
      iyy = (XX3*SIZ*EXAGG)-CEN3+ycent
      ixtext=ixx-45
      iytext=iyy+4
      call toolbx(MOVETO,ixtext,iytext)
      PRINT*,XX3
      call toolbx(MOVETO,ixx,iyy)
      ixx = (FINX2*SIZ)-CEN2+xcent
      call toolbx(LINETO,ixx,iyy)
      XX3 = XX3+DELX3
725   CONTINUE

      XX2=STARTX2
      XX3=STARTX3
      DO 726 WHILE (XX2.LE.FINX2)
      ixx = (XX2*SIZ)-CEN2+xcent
      iyy = (XX3*SIZ*EXAGG)-CEN3+ycent
      ixtext=ixx-20
      iytext=iyy-5
      call toolbx(MOVETO,ixtext,iytext)
      PRINT*,XX2
      call toolbx(MOVETO,ixx,iyy)
      iyy = (FINX3*SIZ*EXAGG)-CEN3+ycent
      call toolbx(LINETO,ixx,iyy)
      XX2 = XX2+DELX2
726   CONTINUE
      call toolbx(PENSIZE,2,2)
      DO 727 I=1,NUMBER
      ixx = (XBEG(I)*SIZ)-CEN2+xcent
      iyy = (YBEG(I)*SIZ*EXAGG)-CEN3+ycent
      call toolbx(MOVETO,ixx,iyy)
      ixx = (XEND(I)*SIZ)-CEN2+xcent
      iyy = (YEND(I)*SIZ*EXAGG)-CEN3+ycent
      call toolbx(LINETO,ixx,iyy)
727   CONTINUE
      call toolbx(PENSIZE,1,1)
```

```
      IF(Displacements) CLOSE(12)
      IF(StressStrain)  CLOSE(11)
      CLOSE(14)                          !!!!!!!

      call toolbx(MOVETO,30,30)
        IF(INDFRIC.EQ.1) PRINT*,"RIGHT LATERAL SET"
        IF(INDFRIC.EQ.2) PRINT*,"LEFT LATERAL SET"
        IF (IGRIDA.EQ.8) PRINT*,"FRIC = ",FRIC


      if(PictPaint.EQ.1)then                              !  if 1 pict plot
      call toolbx(BRINGTOFRONT,plot_window)
      call toolbx(CLOSEPICTURE)
      call toolbx(DRAWPICTURE,picthdl(1),scrrect2)
      call toolbx(SETWINDOWPIC,plot_window,picthdl(1))  ! to have the screen
refreshed
      call toolbx(SHOWWINDOW,plot_window)
      endif
c      call toolbx(SETPORT,tty_window)

********************Output element conditions to disk********************

      IF (IGRIDA.EQ.8) THEN                               !only output elements for
condx 8

      OPEN(18,ACCESS="SEQUENTIAL",STATUS="NEW",FILE="Element condx")   !!!!!!!
      REWIND 18                                                      !!!!!!!
        write(18,995)tab,tab,tab,tab,tab,tab,tab,tab,tab,tab,tab
     1               ,tab,tab,tab,tab                                  !!!!!!!
 995    format('kode',a1,'X2-centre',a1,'X3-centre',a1,'length',a1
     1        ,'angle',a1,'shear slip',a1,'normal slip',a1
     2        ,'sigx',a1,'sigy',a1,'sigxy',a1,'sigshear-f',a1,'signor-f'
     3        ,a1,'coulfault rt',a1,'coulfault lt',a1,'sigshear-opt'
     4        ,a1,'signor-opt',a1,'coulomb optimum')


      DO 115 M=1,NUMB2                          ! calculate at all elements reg1 &
reg2
      SIZE1=2.0*A(M)
      ANGLE=180.0*ATAN2(SINBET(M),COSBET(M))/PI

      CALL initil
      IF(ISET.EQ.0)then
      CALL Calcpo(XM(M),YM(M),U2,U3,SGXX1,SGYY1,SGXY1,0,NUMBE1)          ! reg1 sum
      ELSE
      CALL Calcpo(XM(M),YM(M),U2,U3,SGXX1,SGYY1,SGXY1,                   ! reg2 sum
     +NUMBE1,NUMB1)
      ENDIF
      CALL initil
      IF(ISET.EQ.0)then
      CALL Calcpo(XM(M),YM(M),UU2,UU3,SGXX2,SGYY2,SGXY2,NUMB1,NUMB2)     ! fixed
element sum
      ENDIF

      SGX=SGXX1+SGXX2+PXX
      SGY=SGYY1+SGYY2+PYY
      SGXY=SGXY1+SGXY2+PXY
```

```
      UUU2=UU2+U2
      UUU3=UU3+U3
      E22=(1.0+PR)/E*(SGX-PR*(SGX+SGY))
      E33=(1.0+PR)/E*(SGY-PR*(SGX+SGY))
      VOL=E22+E33
      SHEAR=(SGXY1+SGXY2)*(1.0+PR)/E

*START*****************  Calculate fault coulomb criteria   ****************

        SINT=SINBET(M)
        COST=COSBET(M)

c       SINT=-COSBET(M)        ! because sin - Pi/2 = -cos
c       COST=-SINBET(M)        ! because cos - Pi/2 =  sin    and sign conv

      SFX=SGX-FAULT*PXX
      SFY=SGY-FAULT*PYY
      SFXY=SGXY-FAULT*PXY

      SIGNOR = SFX*COST*COST + 2.0*SFXY*SINT*COST + SFY*SINT*SINT
      SIGSHEAR=(SFY-SFX)*SINT*COST + SFXY*(COST*COST-SINT*SINT)

      If(Plane_stress.eq.0) then
      VALFR= -(SIGSHEAR)+FRIC*(SIGNOR - FLUID*(1+PR)*(SFX+SFY)/3.0)
      VALFL= +(SIGSHEAR)+FRIC*(SIGNOR - FLUID*(1+PR)*(SFX+SFY)/3.0)
                                !plane strain condx
      else
      VALFR= -(SIGSHEAR)+FRIC*(SIGNOR - FLUID*(SFX+SFY)/3.0)
      VALFL= +(SIGSHEAR)+FRIC*(SIGNOR - FLUID*(SFX+SFY)/3.0)
                                !plane stress condx
      endif

      SIGNORF    =  SIGNOR
      SIGSHEARF  =  SIGSHEAR

*END*****************  Calculate fault coulomb criteria   ****************


*START***************  Calculate optimum coulomb criteria   ****************

        PHI = 0.5*ATAN((2*SGXY)/(SGX-SGY)) !calculate angle of principal axes
        COST=COS(PHI)
        SINT=SIN(PHI)
      ERAD1=(SGX*COST*COST+SGY*SINT*SINT+2.0*SGXY*COST*SINT) !principal stress 1
        COST=COS(PHI+ PI/2.0)
        SINT=SIN(PHI+ PI/2.0)
      ERAD2=(SGX*COST*COST+SGY*SINT*SINT+2.0*SGXY*COST*SINT) !principal stress 2
        IF(ERAD2.GE.ERAD1) PHI=PHI+PI/2.0   !set phi to indicate max principal
stress

      If(Plane_stress.eq.0) then
      ERAD3 = PR*(ERAD1+ERAD2)          !plane strain condx
      else
      ERAD3 = 0.0                       !plane stress condx
      endif
```

```
        COST=COS(PHI-ANGBETA-PI/2.0)
        SINT=SIN(PHI-ANGBETA-PI/2.0)

      SFX=SGX-FAULT*PXX
      SFY=SGY-FAULT*PYY
      SFXY=SGXY-FAULT*PXY

      SIGNOR = SFX*COST*COST + 2.0*SFXY*SINT*COST + SFY*SINT*SINT
      SIGSHEAR=(SFY-SFX)*SINT*COST + SFXY*(COST*COST-SINT*SINT)

      If(Plane_stress.eq.0) then
      VAL= -(SIGSHEAR)+FRIC*(SIGNOR - FLUID*(1+PR)*(SFX+SFY)/3.0)
                                !plane strain condx
      else
      VAL= -(SIGSHEAR)+FRIC*(SIGNOR - FLUID*(SFX+SFY)/3.0)
                                !plane stress condx
      endif

*END**************  Calculate optimum coulomb criteria   ****************


      WRITE (18,15) KOD(M),tab,XM(M),tab,YM(M),tab,SIZE1,tab,ANGLE,tab
     1,D(2*M-1),tab,D(2*M),tab,SGX,tab,SGY,tab,SGXY,tab,SIGSHEARF
     2,tab,SIGNORF,tab,VALFR,tab,VALFL,tab,SIGSHEAR,tab,SIGNOR,tab,VAL

  115 CONTINUE

  15   format(I3,a1,G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,
     1 G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,G16.7
     2,a1,G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,G16.7,a1,G16.7)

      CLOSE(18)                         !!!!!!!

*************************************************************************
      ENDIF              ! if statement to output elements only for conx 8

      END


      SUBROUTINE STRAIN(X2,X3,DELX2,DELX3,E22,E22B,E23,E32
     1,E33,E33B,VOL,SHEAR,CURL)

C   This program takes 3 values the origin and adjacent corners of the
C   box in which strain is to be measured. The origin has index 1, the
C   top right index 2 and bottom left index 3. Right is the X-2 direct-
C   ion and down is X-3. E32 is derivative of displacement 3 with res-
C   pect to X-2 and E23 the corresponding 2-derivative with respect to
C   X-3. SHEAR is the shear strain total and NOT the tensor components
C   which would be SHEAR/2. CURL is the rotation  -   clockwise posit-
C   ive. VOL is the volume strain and is the sum of the two linear
C   strains E22 and E33 extension and volume increase are positive.
C
      IMPLICIT REAL*4(A-H,O-Z)
      DIMENSION X2(4),X3(4)
```

```
      A3=X3(2)-X3(1)
      B2=X2(2)-X2(1)
      A2=X2(3)-X2(1)
      B3=X3(3)-X3(1)
      E32=A3/B2
      E23=A2/B3
      E22=(X2(2)-X2(1))/DELX2-1.0
      E22B=(X2(4)-X2(3))/DELX2-1.0
      E33=(X3(3)-X3(1))/DELX3-1.0
      E33B=(X3(4)-X3(2))/DELX3-1.0
      SHEAR=E23+E32
      CURL=E23-E32
      VOL=E22+E33
C     PRINT*,E32,E23,E22,E33
      RETURN
      END

      SUBROUTINE GETSHADE(VAL,DELT,IBASE,INTE,pat)

        IMPLICIT REAL*4(A-H,O-Z)
        integer*1 pat(8)
        integer*1 pat1(8)
        integer*1 pat2(8)
        integer*1 pat3(8)
        integer*1 pat4(8)
        integer*1 pat5(8)
        integer*1 pat6(8)
        integer*1 pat7(8)

        integer*4 INT,INTE,INTEE,IBASE

        INTE=VAL/DELT
        IF(INTE.GE.9)    INTE=9
        IF(INTE.LE.-9)   INTE=-9


      data pat1    /b'00000000',
     +              b'00000000',
     +              b'00000000',
     +              b'00000000',
     +              b'00000000',
     +              b'00000000',
     +              b'00000000',
     +              b'00000000'/

      data pat2    /b'10001000',
     +              b'00000000',
     +              b'00100010',
     +              b'00000000',
     +              b'10001000',
     +              b'00000000',
     +              b'00100010',
     +              b'00000000'/

      data pat3    /b'10001000',
     +              b'00100010',
```

```
     +              b'10001000',
     +              b'00100010',
     +              b'10001000',
     +              b'00100010',
     +              b'10001000',
     +              b'00100010'/

      data pat4    /b'10101010',
     +              b'01010101',
     +              b'10101010',
     +              b'01010101',
     +              b'10101010',
     +              b'01010101',
     +              b'10101010',
     +              b'01010101'/

      data pat5    /b'01110111',
     +              b'11011101',
     +              b'01110111',
     +              b'11011101',
     +              b'01110111',
     +              b'11011101',
     +              b'01110111',
     +              b'11011101'/

      data pat6    /b'01110111',
     +              b'11111111',
     +              b'11011101',
     +              b'11111111',
     +              b'01110111',
     +              b'11111111',
     +              b'11011101',
     +              b'11111111'/

      data pat7    /b'11111111',
     +              b'11111111',
     +              b'11111111',
     +              b'11111111',
     +              b'11111111',
     +              b'11111111',
     +              b'11111111',
     +              b'11111111'/

      INT=IABS(INTE)
      IF(IBASE.EQ.1) INT=INTE+3

      do 10 i=1,8
      pat(i)=pat1(i)
10    continue

      if(INT.GE.1) then
      do 11 i=1,8
      pat(i)=pat2(i)
11    continue
      endif
```

```
      if(INT.GE.2) then
      do 12 i=1,8
      pat(i)=pat3(i)
 12   continue
      endif
      if(INT.GE.3) then
      do 13 i=1,8
      pat(i)=pat4(i)
 13   continue
      endif
      if(INT.GE.4) then
      do 14 i=1,8
      pat(i)=pat5(i)
 14   continue
      endif
      if(INT.GE.5) then
      do 15 i=1,8
      pat(i)=pat6(i)
 15   continue
      endif
      if(INT.GE.6) then
      do 16 i=1,8
      pat(i)=pat7(i)
 16   continue
      endif

        return
        end
```

```
      SUBROUTINE INITIL

      implicit none

      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN

      SXXS=0.0
      SXXN=0.0
      SYYS=0.0
      SYYN=0.0
      SXYS=0.0
      SXYN=0.0

      UXS=0.0
      UXN=0.0
      UYS=0.0
      UYN=0.0

      RETURN
      END
```

```
*       INSING

          subroutine insing (tty_window)

      include demo.inc

      implicit none                        ! helps keep us out of trouble
      integer*4 tty_window                 ! pointer to the tty window

      INTEGER*4 N

      REAL*4 E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,XSYM,YSYM,PXX
     1,PYY,PXY
      INTEGER*4 KSYM,IHALF
      COMMON/S1/E1,E2,PR1,PR2,ZDEPTH,PI,PR,E,KSYM,XSYM
     1,YSYM,PXX,PYY,PXY,IHALF
      REAL*4 XBEG,YBEG,XEND,YEND,BVS,BVN,DPA
      INTEGER*4 NUM
      COMMON/S6/XBEG(500),YBEG(500),XEND(500),YEND(500)
     1,BVS(500),BVN(500),DPA(500),NUM(500)
      INTEGER*4 KODES
      COMMON/S7/KODES(500)
      INTEGER*4 NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      COMMON/S8/NUMBS,NUMOS,NUMBS1,NUMBS2
     1,NUMBE1,NUMBE2,NUMBE3,KSYMI
      REAL*4 XM,YM,A,COSBET,SINBET
      INTEGER*4 KOD
      COMMON/S9/XM(500),YM(500),A(500),COSBET(500)
     1,SINBET(500),KOD(500)
      REAL*4 C,B,D,DIPA
      COMMON/S10/C(1000,1000),B(1000),D(1000),DIPA(1000)
      REAL*4 SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
     1,UXS,UXN,UYS,UYN
      COMMON/S11/SXXS,SXXN,SYYS,SYYN,SXYS,SXYN
        INTEGER*4  NUMB1,NUMB2
      COMMON/S16/ NUMB1,NUMB2

        INTEGER*4 width,height                    ! for growing windows
        INTEGER*2 scrrect
        COMMON/S20/ scrrect(4),width,height
C
C  ------------------------------ 1 ----------------------------------
C   The program supplies a simple start problem that can be interactively
C   modified. A file called example is created that can be editted and
C   read in usind the old routine
C
C
       call toolbx(BRINGTOFRONT,tty_window)
                        call clrtty
      PRINT*," "
      PRINT*," "
      PRINT*,"      Copyright 1986, Alkane Exploration"
      PRINT*," "
      PRINT*,"   **** REMEMBER THE SIGN CONVENTION ****"
      PRINT*," "
      PRINT*,"     Region 1 is always on the left side"
```

```
      PRINT*,"            of any element!!!"
      PRINT*," "
      PRINT*,"    * Compressional strains are positive. "
      PRINT*,"    * Element closure is positive "
      PRINT*,"    * Right lateral motion is positive "
      PRINT*," "
      PRINT*,"   Normal refers to opening for 2-D elements "
      PRINT*,"but to dip-slip motion for 3-D half-space elements."
      PRINT*,"          Reverse motion is positive."
      PRINT*,"Dip angle is only read for 3-D half space elements"
      PRINT*,"       and refers to left side of element"
      PRINT*," "
      PRINT*," "
      PRINT*,"          return to continue"

      PAUSE

C
      INDEX=0
      NUMOS=0     ! # of elements with fixed displacement
      NUMBS1=1    ! # of boundary elements in region1 alone
      NUMBS2=0    ! # elements in region1  and common to 2
      KSYMI=1
      PR1=0.25
      PR2=0.25
      ZDEPTH=12.0
      E1=.7E5
      E2=.7E5
      XSYM=0.0
      YSYM=0.0
      PXX=0.0
      PYY=0.0
      PXY=0.0

  941 PRINT*," 1-  Number of straight-line segments (each containing at
     1 least one"
      PRINT*,"boundary element ) used to define boundaries of region 1"
      PRINT*,"Region 2 can only have common boundaries with Region 1"
      WRITE (*,6) NUMBS1,NUMBS2
    6 FORMAT(" Boundries of 1 only # =",I3,"   Common with 2 =",I3,/)
      IF(KSYMI.NE.5)KSYM=KSYMI
      IHALF=0
      IF(KSYMI.EQ.5)THEN
      PRINT*," 2 -   **** HALF SPACE SOLUTION **** ".
      KSYM=1
      IHALF=1
      END IF
      GO TO (80,85,90,95),KSYM
   80 WRITE (*,7)
      GO TO 100
   85 WRITE (*,8) XSYM
      GO TO 100
   90 WRITE (*,9) YSYM
      GO TO 100
   95 WRITE (*,10) XSYM,YSYM
    7 FORMAT( 34H 2-No symmetry conditions imposed.)
    8 FORMAT( 20H 2-The line X = XS =,G12.4,23H is a line of symmetry.)
```

```
    9 FORMAT( 20H 2-The line Y = YS =,G12.4,23H is a line of symmetry.)
   10 FORMAT( 21H 2-The lines X = XS =,G12.4,13H and Y = YS =,G12.4,
     1 23H are lines of symmetry.)
   12 FORMAT (/,33H 5.xx-component of field stress =,E11.4,//,33H 6.yy-c
     lomponent of field stress =,E11.4,//,33H 7.xy-component of field st
     2ress =,E11.4)
C
  100 CONTINUE
      WRITE (*,11) PR1,PR2,ZDEPTH,E1,E2
   11 FORMAT(/," 3.- Poisson's ratios. REGION 1 =",F7.2,"     REGION 2
     1=",F7.2,"        DEPTH =",F7.2,//,
     1" 4.- Youngs Modulii.   REGION 1 =",E11.4,"  REGION 2
     1=",E11.4)
      WRITE (*,12) PXX,PYY,PXY
      WRITE (*,666) NUMOS
  666 FORMAT (/," 8-Number of elements with fixed relative slip =",I3)
      PRINT*," "
      PRINT*,"DO YOU WISH TO CHANGE VALUES? Type index number or 0 to
     1 continue"
C
C   The following asks questions to be replied to by screen input
C   to change parameters.
C
      READ*,INDEX
      IF(INDEX.EQ.0) GO TO 942
      IF(INDEX.EQ.1) THEN
      PRINT*,"How many boundary line segments? (JUST REGION1,SHARED)"
      READ*,NUMBS1,NUMBS2
      END IF
      IF(INDEX.EQ.2) THEN
      PRINT*,"What symmetry conditions are required?"
      PRINT*,"1. None, 2. x-line, 3. y-line, 4. x- and y-lines"
      PRINT*,"5. Half-space"
      READ*,KSYMI
      IF(KSYMI.EQ.2) THEN
      PRINT*,"New line at x parallel to y"
      READ*,XSYM
      ENDIF
      IF(KSYMI.EQ.3) THEN
      PRINT*,"New line at y parallel to x"
      READ*,YSYM
      END IF
      IF(KSYMI.EQ.4) THEN
      PRINT*,"New line at x parallel to y and at y parallel to x"
      READ*,XSYM,YSYM
      END IF
      END IF
      IF(INDEX.EQ.3) THEN
      PRINT*,"New  Poissonn's ratios (REGION1,REGION2), New Depth"
      READ*,PR1,PR2,ZDEPTH
      END IF
      IF(INDEX.EQ.4) THEN
      PRINT*,"New Young's modulii (REGION1,REGION2)"
      READ*,E1,E2
      END IF
      IF(INDEX.EQ.5) THEN
      PRINT*,"New xx-field stress?"
```

```
      READ*,PXX
      END IF
      IF(INDEX.EQ.6) THEN
      PRINT*,"New yy-field stress?"
      READ*,PYY
      END IF
      IF(INDEX.EQ.7) THEN
      PRINT*,"New xy-field stress?"
      READ*,PXY
      END IF
      IF(INDEX.EQ.8) THEN
      PRINT*,"How many elements with fixed relative slip then?"
      READ*,NUMOS
      END IF
      GO TO 941
 942  CONTINUE
C
      REWIND 4
      WRITE(4,9902)
      WRITE(4,9901) NUMBS1,NUMBS2,NUMOS,KSYMI
     1,PR1,PR2,ZDEPTH,E1,E2,XSYM,YSYM,PXX,PYY,PXY
9902  FORMAT('************************    TWO LINES FOR A LABEL    ******
     +*****************'
     +,/,'                              (or leave them blank)')
9901  FORMAT('#reg1=',I3,'  #reg2=',I3,'   #fixed=',I3,'  sym=',I3,/,
     +' PR1=',G15.3,'  PR2=',G15.3,'DEPTH=',G15.3,/,
     +'  E1=',E15.6,'   E2=',E15.6,/,
     +'XSYM=',G15.3,' YSYM=',G15.3,/,
     +' PXX=',E15.6,'  PYY=',E15.6,'  PXY=',E15.6,//,
     +'  #   X-start    Y-start     X-fin      Y-fin   Kode   shear
     +  normal    dip angle',/,
     +'xxx xxxxxxxxx xxxxxxxxx xxxxxxxxx xxxxxxxxx xxx xxxxxxxxx x
     +xxxxxxxxx xxxxxxxxx')


C
C     ----------------------------------------------------------------

C
C    ------------------------------  3  ---------------------------------
C      Note that although boundary elements and faults are stored to-
C      gether and with the same format (only distiguished by the KODES
C      number), different commands are used to modify faults and bound-
C      ary element data.
C

C
      NUM(1)=1
      XBEG(1)=-2.1
      YBEG(1)=-2.1
      XEND(1)=2.1
      YEND(1)=2.1
      KODES(1)=12
      ZDEPTH=12.0
      BVS(1)=1.0
      BVN(1)=0.0
      DPA(1)=45.0
```

```
C
 971  CONTINUE
      PRINT*,"BOUNDARY ELEMENTS"
      PRINT*," # NUM       XBEG        YBEG        XEND        YEND    KODES
     1    BVS        BVN      DPA"
      DO 973 N=1,NUMBS1
      WRITE(*,921)N,NUM(N),XBEG(N),YBEG(N),XEND(N),YEND(N),KODES(N)
     1,BVS(N),BVN(N),DPA(N)
 921  FORMAT(I2,I3,4X,G10.4,1X,G10.4,1X,G10.4,1X,G10.4,1X,I3,1X,G10.4
     +,1X,G10.4,1X,G10.4)
 973  CONTINUE
      PRINT*,"Shared boundary elements. These KODES must = 7,8 or 9"
      DO 974 N=NUMBS1+1,NUMBS1+NUMBS2
      WRITE(*,921)N,NUM(N),XBEG(N),YBEG(N),XEND(N),YEND(N),KODES(N)
     1,BVS(N),BVN(N),DPA(N)
 974  CONTINUE
      PRINT*, "SIGN CONVENTION - Displacement values apply to medium to
     1 the LEFT of the"
      PRINT*,"direction in which co-ords are specified. (exc
     1ept for KODES= 5)"
      PRINT*,"BVS - shear condition, BVN - normal condition, DPA - dip"
      PRINT*," "
      PRINT*,"KODES= 1- 2 stress conditions,          2- 2 displacement c
     1onditions"
      PRINT*,"       3- 1 displacement & 1 stress,    4- 1 stress & 1 dis
     1placement"
      PRINT*,"       5- 1 stress condition & 1 relative displacement con
     1dition"
      PRINT*,"       6- 1 relative displacement condition & 1 stress con
     1dition"
      PRINT*,"       7- Shear and Normal stress and displacement continu
     1ous"
      PRINT*,"       8- Normal stress and displacement continuous."
      PRINT*,"          Shear stress is zero and displacement free."
      PRINT*,'       9- Normal spring rate specified in "shear" Normal f
     1ixed'
      PRINT*,'          stress specified in "normal" Shear is free.'
      PRINT*,"Values pre-fixed by 10 give half-space solutions.   BVN re
     1fers to the dip-slip "
      PRINT*," component and DPA refers to the dip angle."
      PRINT*,"  "
      PRINT*,"press return to continue."
      PRINT*,"DO YOU WISH TO CHANGE VALUES? Type index number or 0 to
     1 continue"
      READ*,N
      IF(N.EQ.0) GO TO 970
      PRINT*, "Use free format separated by commas"
      PRINT*,"for- # of sub-elements, XBEG,YBEG,XEND,YEND,KODES,BVS,BVN
     1,DPA"
      READ*,NUM(N),XBEG(N),YBEG(N),XEND(N),YEND(N),KODES(N)
     1,BVS(N),BVN(N),DPA(N)
      GO TO 971
 970  CONTINUE
 975  CONTINUE
      PRINT*,"ELEMENTS WITH FIXED RELATIVE SLIP"
      PRINT*,"  #        XBEG        YBEG        XEND        YEND    KODES
     1Shear slip  Normal slip    Dip angle"
```

```
      DO 978 N=NUMBS1+NUMBS2+1,NUMBS1+NUMBS2+NUMOS
      NUM(N)=1
      WRITE(*,923)N,XBEG(N),YBEG(N),XEND(N),YEND(N),KODES(N)
     1,BVS(N),BVN(N),DPA(N)
  923 FORMAT(I3,4X,G10.4,1X,G10.4,1X,G10.4,1X,G10.4,1X,I3,1X,G10.4
     +,1X,G10.4,1X,G10.4)
  978 CONTINUE
      PRINT*,"NOTE- The displacements  are  relative  slip  and not"
      PRINT*,"       absolute displacements as for boundary elements."
      PRINT*,"Elements with constant slip are specified with "
      PRINT*,"KODE=0. Use KODE=10 for tapered slip. "
      PRINT*,"KODE=100 for half-space. Normal refers to Dip-slip "
      PRINT*," "
      PRINT*,  "DO YOU WISH TO CHANGE VALUES? Type index number or 0 to
     1 continue"
      READ*,N
      IF(N.EQ.0) GO TO 976
      PRINT*, "Use free format separated by commas"
      PRINT*," XBEG, YBEG, XEND, YEND, KODE, Shear slip, Normal slip,
     1Dip angle"
      READ*,XBEG(N),YBEG(N),XEND(N),YEND(N),KODES(N)
     1,BVS(N),BVN(N),DPA(N)
      GO TO 975
  976 CONTINUE
C
      DO 977 N=1,NUMBS1+NUMBS2+NUMOS
      WRITE(4,920)NUM(N),XBEG(N),YBEG(N),XEND(N),YEND(N),KODES(N)
     1,BVS(N),BVN(N),DPA(N)
  920 FORMAT(I3,1X,G10.4,1X,G10.4,1X,G10.4,1X,G10.4,1X,I3,1X,G10.4,1X,
     +G10.4,1X,G10.4)
  977 CONTINUE
      call clrtty
      PRINT*,'To plot the modified or unmodified data created by "New"
     +  run   "Calculate"  and'
      PRINT*,'then run "Plot"'
      PRINT*,' '
      PRINT*,'Creating complex data files using "New" is clumsy. Two al
     +ternatives are possible.'
      PRINT*,'Both  operate  on  a  file  called  "example" that  has
     +been  created  by "New"'
      PRINT*,' '
      PRINT*,'  ********** The file can only be reread by "Old" after i
     +t is renamed *********  '
      PRINT*," "
      PRINT*,'1 - Exit program and modify  "example"  using Edit by  ad
     +ding  elements  etc. in'
      PRINT*,'     the appropriate format.'
      PRINT*,'     (If in doubt about the meaning of parameters  re-run
     +"New")'
      PRINT*,'     Re-run the program reading the modified file using th
     +e "Old" option.'
      PRINT*,' '
      PRINT*,'2 - New elements can be added graphically to the end of
     +the example  file after'
      PRINT*,'     running "Calculate" and "Plot".'
      PRINT*,'     Select the undeformed grid (respond 0 to 9)  and  adj
     +ust  the  parameters to'
```

```
      PRINT*,'    suit the problem.'
      PRINT*,'    Element ends are picked in pairs using the cursor.
     +Respond to the  questions'
      PRINT*,'    to input the other parameters.'
      PRINT*,'    The new elements are  added  at the end of the  "exam
     +ple"  file and  must be '
      PRINT*,'    moved to the appropriate  position to replace the defa
     +ult element. The other'
      PRINT*,'    parameters must also be adjusted as appropriate.'

      WRITE(4,50)

      WRITE(4,51)

50    FORMAT(' '/,
     +'The last data line defined by "Reg1", "Reg2" and "fixed"  must a
     +lways end',/,
     +'in a carriage return or the it will be ignored. Anything after t
     +hat  line,',/,
     +'such as this material, will also be ignored.',/,
     +'The number of free elements is specified by "Reg1" and "Reg2"  a
     +nd  fixed',/,
     +'elements  by  "fixed".  They must be correctly specified.  Free
     + elements',/,
     +'preceed fixed elements in the list',/,
     +'Run NEW for more information on parameters',/,
     +'Reg1 refers to elements with only region 1 boundaries',/,
     +'Reg2 refers to elements common to regions 1 and 2',/,/,
     +'Notes  can  be  added  at  the  ends  of  lines for convenience
     +and  will',/,
     +'be ignored by the program')
51    FORMAT('  ',/,
     +'If new elements have been added from the screen,  they  will app
     +ear below',/,
     +'and must be moved to the appropriate position.',/)


      RETURN
      END
```

```
*       MAKELS

      Subroutine Makels(plot_window,data_window,IX,IY,IXX,IYY,Itimes)
      implicit none
      include demo.inc
      include quickdraw.inc
        integer*4 data_window            ! pointer to the tty window
        integer*4 plot_window            ! pointer to the graphics window
        INTEGER*4 IX,IY,IXX,IYY,icx,icy,icxx,icyy,Itimes
        INTEGER*4 NUMBS1,NUMBS2,NUMOS,KSYMI,N,KODE
         REAL*4 PR1,PR2,E1,E2,XSYM,YSYM,PXX,PYY,PXY
     1,BVS,BVN
        real*4 THET,dx,dy
        real*4 XSTART,YSTART,XFIN,YFIN

        character*4 YesNo

        REAL*4       offsetx,offsety,scalex,scaley
        LOGICAL*4    in_grid
      COMMON/S17/ offsetx,offsety,scalex,scaley,in_grid

        YesNo='x'

      call toolbx(SETPORT,plot_window)
      XSTART=FLOAT(IX+offsetx)*scalex
      YSTART=FLOAT(IY+offsety)*scaley
      XFIN  =FLOAT(IXX+offsetx)*scalex
      YFIN  =FLOAT(IYY+offsety)*scaley
      call toolbx(MOVETO,IX,IY)
      call toolbx(LINETO,IXX,IYY)
        dx=FLOAT(IXX-IX)
        dy=FLOAT(IYY-IY)
        THET= ATAN2(dy,dx)
        icx=(IXX+IX)/2
        icy=(IYY+IY)/2
        icxx=icx+INT(10.0*SIN(THET))
        icyy=icy-INT(10.0*COS(THET))
        call toolbx(MOVETO,icx,icy)
        call toolbx(LINETO,icxx,icyy)

      call toolbx(MOVETO,3,40)
      PRINT*,'                                                  '
     +                                                          '
      PRINT*,'                                                  '
     +                                                          '
      PRINT*,'                                                  '
     +                                                          '
      PRINT*,'                                                  '
      call toolbx(MOVETO,3,40)
      PRINT*, 'Number of elements?'
      READ*,N

      call toolbx(MOVETO,3,40)
      PRINT*,'                                  '
      PRINT*,'                                  '

      call toolbx(MOVETO,3,40)
```

```
      PRINT*, 'KODE? - refer to NEW'
      READ*,KODE

      call toolbx(MOVETO,3,40)
      PRINT*,'                                  '
      PRINT*,'                                  '

      call toolbx(MOVETO,3,40)
      PRINT*, 'shear component?      '
      READ*,BVS

      call toolbx(MOVETO,3,40)
      PRINT*,'                                  '
      PRINT*,'                                  '

      call toolbx(MOVETO,3,40)
      PRINT*, 'normal component?      '
      READ*,BVN

      call toolbx(MOVETO,3,40)
      WRITE(*,9901)
 9901 FORMAT(
     +' #    X-start    Y-start     X-fin      Y-fin   Kode   along
     +  normal')
      WRITE(*,920) N,XSTART,YSTART,XFIN,YFIN,KODE
     1,BVS,BVN
      PRINT*, '*** "c" - continue boundary, "n" - new boundary, "return
     1" - abandon ***'

      call toolbx(SETPORT,data_window)
         Read*,YesNo
      call toolbx(SETPORT,plot_window)
      If(YesNo.EQ.'n'.or.YesNo.EQ.'c') then
        call toolbx(PENSIZE,2,2)
        call toolbx(MOVETO,IX,IY)
        call toolbx(LINETO,IXX,IYY)
        call toolbx(MOVETO,icx,icy)
        call toolbx(LINETO,icxx,icyy)
        call toolbx(PENNORMAL)

      WRITE(4,920) N,XSTART,YSTART,XFIN,YFIN,KODE
     1,BVS,BVN
  920 FORMAT(I3,1X,G10.4,1X,G10.4,1X,G10.4,1X,G10.4,1X,I3,1X,G10.4,1X,
     +G10.4)
      endif

      If(YesNo.EQ.'c')then
      Itimes=2
      else
      Itimes=1
      endif

      return
      end
```

Accession number no longer required.

ENCLOSURE 2

1.2.3.2 .4.12

QUALITY ASSURANCE GRADING REPORT

N-QA-095
7/90

PART I - IDENTIFICATION AND DEFINITION: ☐ ITEM ☒ ACTIVITY WBS 1.2.3.2.8.4.12 PAGE 1 OF 5

TITLE/DESCRIPTION Tectonic Models and Synthesis (except Activities 2 and 3) **REPORT NO.** G12328412 **REV. NO.** 0

RESPONSIBLE ORGANIZATION U.S. Geological Survey

REVISION(S) OF Q-LIST, QUALITY ACTIVITIES LIST, NON-SELECTION RECORD, AND SUPPORTING DOCUMENTATION USED:
Study Plan No. 8.3.1.17.4.12, Rev. 0; Quality Activities List, Rev. 3; WBS Index and Dictionary

(Attach additional, definitive information, as necessary, to fully define the subject item or activity and support the position expressed in this QAG Report.)

PART II - STATEMENT OF IMPORTANCE

Section A: (Check the appropriate areas) ☐ Public Radiological Safety (Q-List) ☐ Waste Isolation (Q-List)

☒ Performance Assessment (QAL) ☒ Site Characterization (QAL) ☐ Potential Adverse Impact on Natural Barrier(s) (QAL) ☐ NA (Complete Section B)

Section B: (Check the appropriate areas) ☐ Worker Radiological Safety (Att.) ☐ Operational Reliability (Att.)

☐ Other (Provide explanation) (Att:) ☒ NA (Provide explanation) (ATT. 1)

PART III - GRADING:

QA CRITERIA	APPLICABLE (YES or NO)	JUSTIFICATION IF NOT APPLICABLE (Reference)*	EXCEPTION(S) TO CRITERIA SUBPARTS (Reference)*
1. ORGANIZATION	Yes	NA	No Exceptions
2. QA PROGRAM	Yes	NA	No Exceptions
3. DESIGN CONTROL	No	Attachment 1	NA
4. PROCUREMENT DOCUMENT CONTROL	Yes	NA	No Exceptions
5. PLANS, PROCEDURES, INSTRUCTIONS, AND DRAWINGS	Yes	NA	No Exceptions
6. DOCUMENT CONTROL	Yes	NA	No Exceptions
7. CONTROL OF PURCHASED ITEMS AND SERVICES	Yes	NA	No Exceptions
8. IDENT. & CONTROL OF MTRLS, PARTS, CMPNTS, & SMPLS	No	Attachment 1	NA
9. CONTROL OF PROCESSES	No	Attachment 1	NA
10. INSPECTION	No	Attachment 1	NA
11. TEST CONTROL	No	Attachment 1	NA
12. CONTROL OF MEASURING AND TESTING EQUIPMENT	No	Attachment 1	NA
13. HANDLING, SHIPPING, AND STORAGE	No	Attachment 1	NA
14. INSPECTION, TEST, AND OPERATING STATUS	No	Attachment 1	NA
15. CONTROL OF NONCONFORMING CONDITIONS	Yes	NA	No Exceptions
16. CORRECTIVE ACTION	Yes	NA	No Exceptions
17. QA RECORDS	Yes	NA	No Exceptions
18. AUDITS	Yes	NA	No Exceptions
19. COMPUTER SOFTWARE	Yes	NA	No Exceptions
20. SCIENTIFIC INVESTIGATION CONTROL	Yes	NA	No Exceptions

* Reference attached justification or explanations.

PART IV - APPROVALS:

for R.F. Fox 6-10-91
Preparer's Signature Date

6/11/91 6/11/91
QA Manager's Signature Date TPO's Signature Date

QRB ACCEPTANCE:

6/25/91
QRB Chairman's Signature Date

QUALITY ASSURANCE GRADING REPORT
CONTINUATION SHEET

PART I - IDENTIFICATION AND DEFINITION

WBS 1.2.3.2.8.4.12 - Tectonic Models and Synthesis

Work Breakdown Structure (WBS) Element 1.2.3.2.8.4.12 is primarily designed to 1) synthesize data relevant to tectonics, 2) develop a model or range of models that establishes the causal relation between application of tectonic forces and formation of structures observed at Yucca Mountain and vicinity, 3) link observed rates of formation of those structures with regional rates of crustal strain, 4) forecast changes in tectonic setting and the manner in which those changes will affect both the regional crustal strain rate and tectonic stability in the Yucca Mountain region, 5) estimate the effect of those changes on rate and nature of crustal strain at Yucca Mountain and vicinity, and 6) estimate the future rate of tectonic processes at Yucca Mountain. These six objectives are incorporated in three SCP Study Plan Activities.

WBS Element 1.2.3.2.8.4.12 corresponds to one Site Characterization Plan (SCP) Study which is divided into three SCP Activities. In Activity 2 (Evaluate tectonic models), data pertaining to tectonic cycles, including timing and localization of faulting, fracturing, and basaltic volcanism will be synthesized. Alternative conceptual tectonic models will be formulated, and the degree to which those models qualitatively and quantitatively incorporate and reconcile information on the parameters of this Activity will be evaluated. The objective of Activity 3 (Evaluate tectonic disruption sequences) is to evaluate disruption sequences involving faulting, folding,uplift and subsidence, and volcanism that are of potential significance to design or performance of the repository. Activities 2 and 3 will be covered in a separate grading report.

The Activity pertinent to this QA Grading Report is:

Activity 1 - Evaluate tectonic processes and tectonic stability at the site
Study Plan 8.3.1.17.4.12, Sec. 3.1

Activity 1 includes compilation and interpretation of geologic, gravity, and magnetic maps, synthesis of geologic and geophysical studies, and preparation of topical reports on Quaternary wrench faulting, detachment faulting, normal faulting, and left-lateral strike-slip faulting. No samples or equipment needing calibration are required to accomplish this activity. Activity 1 involves procurement of services, which will be controlled. Computer software, if used for data acquisition, data reduction, or other technical functions of this Activity will have controls applied.

PART II - STATEMENT OF IMPORTANCE, SECTION A

WBS Element 1.2.3.2.8.4.12 is a Study subordinate to the Quality Activities List No. 1.2.3.2.8. Work performed under this WBS element is cited in the Site Characterization Plan. There is a probability that this activity may provide input to be used in Performance Assessment.

PART II – STATEMENT OF IMPORTANCE, SECTION B

There are no worker radiological safety, operational reliability, or other issues for this Part associated with this activity.

PART III – GRADING

This Quality Assurance Grading Report addresses Activity 1 of WBS Element 1.2.3.2.8.4.12. The following are justifications for exempting the listed quality assurance criteria:

Section 3: Design Control

Because the USGS performs no hardware design functions and has no responsibilities for design, those specific provisions pertaining to design control are omitted from this QAG Report.

Section 8: Identification and Control of materials, Parts, Components, and Samples

Information used in this activity is from a compilation of maps; therefore, there are no sample collection or handling requirements for WBS Element 1.2.3.2.8.4.12 and the requirements of this Section are not applicable.

Section 9: Control of Processes

The YMP-USGS scientific investigations are controlled by technical procedures and document controls as specified by other sections. Accordingly, controls in the sense of process control as specified by this Section are not pertinent to the YMP-USGS work, and the requirements of this Section are not applicable to this QAG Report. Applicable requirements are provided by Sections 5 and 20.

Section 10: Inspection

The requirements of this Section apply to engineered items only and do not apply to scientific investigation activities.

Section 11: Test Control

The requirements of this Section apply to engineered items only and do not apply to scientific investigation activities.

Section 12: Control of Measuring and Test Equipment

WBS element 1.2.3.2.8.4.12 does not require measuring or test equipment to complete its objectives; therefore, the requirements of this Section are not applicable.

Section 13: Handling, Shipping, and Storage

There are no handling, shipping, or storage requirements for WBS Element 1.2.3.2.8.4.12; therefore, the requirements of this Section are not applicable.

Section 14: Inspection, Test, and Operating Status

The requirements of this Section apply to engineered items only and do not apply to scientific investigation activities.

WORK SHEET FOR EVALUATION OF CHARACTERISTICS

N-QA-094
02/90

TITLE OF ITEM ☐ OR ACTIVITY ☒ PAGE 5 OF 5

Tectonic Models and Synthesis

REPORT NO. G12328412 REV. NO. 0

RESPONSIBLE ORGANIZATION U.S. Geological Survey

NAME OF PREPARER K.F. Fox

CHARACTERISTIC	EVALUATION STATEMENT

1. REPRODUCIBILITY OR EASE OF REPLACEMENT:

No data is generated by this activity; rather, data from other activities is synthesized and interpreted. Required control is thus limited to control of reports and documents.

2. COMPLEXITY:

This activity requires significant input from several other studies. Controls will be applied accordingly.

3. QUALITY HISTORY:

Tectonic evaluations in the U.S. have been done routinely by the USGS for many years. There are no notable difficulties with quality history or demonstrated needs for extensive external quality controls.

4. STANDARDIZATION:

This is a largely interpretive synthesis activity having minimal standardized procedures. Controls will be applied accordingly.

5. AVAILABLE CODES AND STANDARDS:

This activity has few to no standard techniques; controls will be applied accordingly.

6. NEED FOR PROCESS CONTROL:

These activities will be controlled by technical procedures and document controls. External process controls will not be required.

7. SPECIAL HANDLING, SHIPPING, AND STORAGE:

This activity requires no special handling, shipping, or storage controls.

W.R. Lange for K.F. Fox 6-10-91

PREPARER (Signature and Date)

YMP-USGS ACTIVITY CONTROLS SPECIFICATION REPORT

WBS#: 1.2.9.3
QA: QA

PART I - IDENTIFICATION AND DEFINITION

TITLE Tectonic Models and Synthesis

PURPOSE Initiation of grading control for Activities 2 and 3 (see Attachment 1)

Report No. YMP-USGS-ACS-G12328412-1, R0

Study Plan No. 8.3.1.17.4.12

PART II A - INDICATION OF IMPORTANCE

- [ ] Public Radiological Safety
- [ ] Waste Isolation
- [x] Performance Assessment
- [x] Site Characterization
- [ ] Adverse Impact on Barrier
- [ ] Worker Radiological Safety
- [ ] Operational Reliability
- [ ] Other (Provide Explanation (Att.)
- [ ] Not Applicable (Att. 1)

PART II B - INDICATION OF CHARACTERISTICS

- [ ] Reproducibility/Replacement
- [ ] Complexity
- [ ] Standardization
- [ ] Available Codes/Standards
- [ ] Need for Controls
- [x] Activity Importance
- [ ] Interface Activities
- [ ] Impact on Barriers
- [ ] Cost and Schedule
- [ ] None of the Above

PART III - ASSIGNMENT OF CONTROLS

Criteria	Applies	Applicable Quality Assurance Procedures	Justifications
1	Yes	QMP-1.01, AP-5.19Q TGR 4/19/93	N/A
2	Yes	QMP-2.01, -2.02, -2.05, -2.07, -2.08	N/A
3	Yes	QMP-3.03, -3.04, -3.05, -3.07, -3.10, -3.11, -3.13, -3.15, ~~and AP-5.19Q~~ TGR 4/19/93	N/A
4	Yes	QMP-4.01, -4.02	N/A
5	Yes	QMP-5.01, -5.02, -5.03, -5.04, -5.05, AP-1.10Q	N/A
6	Yes	QMP-6.01	N/A
7	Yes	QMP-7.01, -7.04	N/A
8	Yes	QMP-8.01, 8.03, AP-5.1Q, -5.9Q, -6.3Q, -6.4Q, -6.26Q	N/A
12	Yes	QMP-12.01	N/A
13	Yes	QMP-13.01	N/A
15	Yes	QMP-15.01	N/A
16	Yes	QMP-16.01, -16.02, 16.03	N/A
17	Yes	QMP-17.01, -17.03	N/A
18	Yes	QMP-18.01, -18.02	N/A

NOTE: Section 9 applies only to special processes; Sections 10, 11, and 14 apply to engineered items, per QARD Matrix.

PART IV - APPROVALS

Preparer	Date	GAC Chairperson	Date	QA Manager	Date	Chief, YMPB	Date
John W Whitney	24 Feb 93	Douglas P Hoxie	04-20-93	[illegible]	4/20/93	Larry P. Hom	4/20/93

ACTIVITY CONTROLS SPECIFICATION REPORT
Continuation Sheet

REPORT NO. YMP-USGS-ACS-G12328412-1, R0

PART I - IDENTIFICATION AND DEFINITION

WBS No. 1.2.3.2.8.4.12 - Tectonic Models and Synthesis

Work Breakdown Structure (WBS) Element 1.2.3.2.8.4.12 is primarily designed to 1) synthesize data relevant to tectonics, 2) develop a model or range of models that establishes the causal relation between application of tectonic forces and formation of structures observed at Yucca Mountain and vicinity, 3) link observed rates of formation of those structures with regional rates of crustal strain, 4) forecast changes in tectonic setting and the manner in which those changes will affect both the regional crustal strain rate and tectonic stability in the Yucca Mountain region, 5) estimate the effect of those changes on rate and nature of crustal strain at Yucca Mountain and vicinity, and 6) estimate the future rate of tectonic processes at Yucca Mountain. These six objectives are incorporated in three SCP Study Plan Activities.

WBS Element 1.2.3.2.8.4.12 corresponds to one Site Characterization Plan (SCP) Study Plan which is divided into three SCP Activities. The purpose for this Activity Controls Specification Report is to bring two of the three activities under quality assurance grading control. Activity 1, Evaluate tectonic processes and tectonic stability at the site, is covered under Quality Assurance Grading Report No. G12328412, R0. The Activities covered by this report are:

Activity 2 Evaluate tectonic models, (Study Plan 8.3.1.17.4.12.2, Section 3.2)

Activity 3 Evaluate tectonic disruption sequences, (Study Plan 8.3.1.17.4.12.3, Section 3.3)

PART II - INDICATION OF IMPORTANCE, SECTION A

Work performed under WBS Element 1.2.3.2.8.4.12 is cited in the Site Characterization Plan. There are no public or worker radiological safety, waste isolation, adverse impact on barriers, or operational reliability issues associated with these activities.

PART II - INDICATION OF CHARACTERISTICS, SECTION B

The key characteristic used in preparing this report was that of Activity Importance as it relates to the importance of erroneous data and data used to assess performance.

Part III - ASSIGNMENT OF CONTROLS

At this stage of the grading process and for the purpose of this Activity Controls Specification Report, it has been determined that all quality assurance controls are applicable for both activities. As need is determined, further grading may be addressed in subsequent grading reports.