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AN ABSTRACT OF THE THESIS OF Carl Fredrick Gullixson for
the Master of Science in Geology presented June 12, 1981.

Title: The Structure, Geologic Evolution and Regional
Significance of the Bethel Creek - North Fork Area,
Coos and Curry Counties, Oregon.

APPROVED BY MEMBERS OF THE THESIS COMMITTEE:

Gilbert T. Benson, Chairman

Ansel G. Johnson

Robert O. Van Atta

The Bethel Creek - North Fork area, astride the
Coos - Curry County line, near the coast in southwestern
Oregon consists of Jurassic Otter Point Formation, a mélangé
complex, and the lower and middle Eocene Roseburg and
Lookingglass Formations, part of a prograding depositional
sequence. These units form four north trending belts
through the area. On the basis of differing structural
style and lithology, three structural units are dis-
tinguished in the area: the Mélangé Terrane, comprising

western and eastern belts of Otter Point Formation; the fault bounded North Fork Block, consisting of the Roseburg and Lookingglass Formations; and the fault bounded Morton Creek Block, consisting of the Roseburg Formation. Rocks of the North Fork Block were deposited in a linear basin between "wedges" of the underlying Otter Point Mélange which formed during continental margin accretion. During the deposition of the Roseburg and Lookingglass Formations, the North Fork Block was deformed into a gently plunging syncline and the entire block was uplifted along reverse faults developed at the contacts between the North Fork Block and the surrounding Mélange Terrane. The Morton Creek Block may have formed as a "fault slice" of the North Fork Block displaced southward along a left lateral shear zone. Fold axis patterns in both the North Fork and Morton Creek Blocks tend to confirm this interpretation.

THE STRUCTURE, GEOLOGIC EVOLUTION AND REGIONAL SIGNIFICANCE
OF THE BETHEL CREEK - NORTH FORK AREA,
COOS AND CURRY COUNTIES, OREGON

by
CARL FREDRICK GULLIXSON

A thesis submitted in partial fulfillment of the
requirements for the degree of

MASTER OF SCIENCE
in
GEOLOGY

Portland State University

1981

TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

The members of the Committee approve the thesis of
Carl Fredrick Gullixson presented June 12, 1981.

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INTRODUCTION

LOCATION

The Bethel Creek - North Fork area is located in the northwestern Klamath Mountains of Oregon. The area studied comprises approximately 72 square kilometers (28 square miles) astride the Coos County - Curry County line, between Floras Creek to the south and Fourmile Creek to the north. The location of the Bethel Creek - North Fork area is shown in Figure 3. Access to the area is via U.S. Highway 101 and Langlois Mt. and Bethel Creek Roads.

PURPOSE

The original purpose of this study was a detailed structural analysis of the Jurassic Otter Point Formation in order to determine if the Canyonville Fault Zone, which forms the northern boundary of the Klamath Mountains in the Riddle - Canyonville area (Benson and Perttu, 1980), extends westward to the coast and, if possible, to characterize the structure of the Otter Point Formation. Further, a detailed examination of the structural and stratigraphic relationships between the Otter Point Formation and the Eocene Roseburg and Lookingglass Formations was to be performed in an attempt to determine the tectonic history of the area.

Figure 3. Index map showing the location of the Bethel Creek - North Fork area.

Due to the inaccessability of the area and poorly exposed to non-existant outcrops, only a limited structural analysis of the Otter Point Formation was possible. Much time was spent, however, in examining the structural and stratigraphic relationships between the Otter Point, Roseburg, and Lookingglass Formations and collecting pertinent structural data. This data, its interpretation and possible regional significance have become the major focus of this study.

PREVIOUS WORK

The earliest formal geologic investigation of the Bethel Creek - North Fork area was reconnaissance mapping by J.S. Diller (1903) as part of the Port Orford Folio. More recently, Phillips (1968) and Brownfield (1972) mapped the area as part of Master's theses with emphasis on the Tertiary stratigraphy and structure. Baldwin and others (1973) covered the northern portion of the area as part of a map and report on the geology and mineral resources of Coos County. Baldwin (1974) included the Bethel Creek - North Fork area in a report on the Eocene stratigraphy of southwestern Oregon. Beaulieu (1976) and Ramp (1977) also included the southern portion of the area in compilation maps and reports on Curry County. Coleman and Lanphere (1971) studied the glaucophane schists within the Otter Point Formation.

PROCEDURE

Most of the data used in this study were obtained by observation in the field. Contacts between major units and larger faults were noted on aerial photographs and then checked in the field. Low altitude black and white photos and a few high altitude color infra-red photos were used. Attitudes and aerial photo data were plotted on an enlargement (1:24,000) of the Langlois Quadrangle (1:62,500) topographic map.

Data from previous investigators (Phillips, 1968; Brownfield, 1972; and Baldwin and others, 1973) were used to complete areas held inaccessible by uncooperative land owners. These data were field checked where possible and modified as necessary.

To facilitate the analysis of structural data, beta and pi diagrams were constructed from field observations using a Honeywell 66/20 computer and programs PIPLOT and BETACAL. Both programs are listed and documented in Appendix A. The computer generated diagrams were hand contoured and reduced to a more usable size.

Petrographic thin section analyses were performed on 20 samples from all major rock units. These analyses, together with descriptions of numerous hand samples, were used in correlation of units and in general description.

OUTLINE OF REGIONAL (BEDROCK) GEOLOGY

The geology of the northern Klamath Mountains is very complex and not entirely understood. The geologic complexity is compounded by inaccessability and cover. The following quote from CASCADIA: The Geologic Evolution of the Pacific Northwest (McKee, 1972), eloquently states the problem.

The principal problems blocking geologic synthesis have been the dense vegetation throughout the region, the steep terrain (which does not necessarily mean good rock exposure), the lithologic monotony of many of the formations, a paucity of fossils, and extreme structural complexity. The Klamath Mountains geologists must think longingly sometimes of the glacial erosion that has stripped the soil cover from ranges in the northern part of the Cordillera. He might even wish for a good southern California type brush fire!

Pre-Jurassic

No pre-Mesozoic rocks are known to occur in the northern Klamath Mountains. Metavolcanic and metasedimentary rocks of the Triassic Applegate Group occur along the eastern margin of the Klamath Mountains (McKee, 1972) (Figure 4).

Jurassic

Five Jurassic formations occur in the northern Klamath Mountains. Four of these form an accreting margin assemblage (McKee, 1972): from east to west, the Galice, Rogue, Dothan, and Otter Point Formations. Rocks of the

Figure 4. Generalized geologic map of the northern Klamath Mountains Province, Oregon. A - Applegate Group, G - Galice Formation, R - Rogue Formation, D - Dothan Formation, O - Otter Point Formation, C - Colebrooke Schist, M - Myrtle Group, T - Tertiary formations, CR - Cascade Range (modified from McKee, 1972).

Galice Formation constitute material laid down in a back-arc basin environment. Rocks of the Rogue Formation represent the volcanic arc (Wells and Walker, 1953; Helming, 1966; Beaulieu, 1971). Rocks of the Dothan Formation represent the fore-arc basin fill. The Otter Point Formation is a mélangé complex and represents the trench fill-subduction complex (Hsu, 1968; Connelly, 1978).

The structure within these formations varies, locally, from the moderate deformation of the Galice, Rogue, and Dothan Formations to the severe deformation characteristic of the Otter Point Formation. Generally, all the formations exhibit greater deformation near the contacts. The regional geology is shown in Figure 4. The arcuate trend is composed of smaller arcuate belts, each consisting of one formation. East dipping (thrust?) faults are common and indicate considerable east-west compression.

The Colebrooke Schist is limited to the northwestern Klamath Mountains (Figure 4). It overlies and is in thrust fault contact with the Dothan and Otter Point Formations (Coleman, 1972).

Cretaceous

Cretaceous rocks in the northern Klamath Mountains are limited to conglomerates and sandstones of the Jura-Cretaceous Myrtle Group; the late Jurassic Riddle Formation and the early Cretaceous Days Creek Formation. The Riddle and Days Creek Formations seem to represent molasse (Benson,

pers. comm., 1978).

Tertiary

Tertiary formations in the northern Klamath Mountains include, in order of decreasing age, the Eocene Roseburg, Lookingglass, Flourney, Tyee, and Coaledo Formations; the Eo-Oligocene Bastendorff and Tunnel Point Formations; and the Pliocene Empire Formation (Baldwin and others, 1973; Baldwin, 1974). Two depositional basins are shown in Figure 5; the large, eastern, Tyee Basin and the smaller, western, South Slough Basin. Deposition within the Tyee Basin was controlled, at least in part, by the east-west trending Canyonville Fault Zone (CFZ, Figure 5) (Perttu, 1976; Koler, 1979; Benson and Perttu, 1980). Deposition within the South Slough Basin was probably structurally controlled, perhaps by the Sixes River Fault Zone (SRFZ, Figure 5). Formations within the Tyee Basin include the Roseburg, Lookingglass, Flourney, Tyee, and Elkton Formations. Within the South Slough Basin, in addition to the above listed formations, the Coaledo, Bastendorff, Tunnel Point, and Empire Formations occur. Rock types within both basins seem to represent prograding depositional sequences (Baldwin and others, 1973; Baldwin, 1974; Koler, 1979).

Structure within the Tertiary rocks is highly variable, but is generally gently plunging, north trending anticlines and synclines (Baldwin and others, 1973; Baldwin, 1974).

Figure 5. Generalized map showing the location and extent of the Tyee and South Slough Basins. SRFZ - Sixes River Fault Zone, CFZ - Canyonville Fault Zone (modified from Ramp, 1969 and Coleman and Lanphere, 1971).

GEOLOGY

Three formations make up the bedrock units in the Bethel Creek - North Fork area. Lowermost in the section is the upper Jurassic Otter Point Formation (Koch, 1966). The Otter Point Formation is a mélangé complex consisting of native and exotic blocks in a pervasively sheared matrix of mudstone and argillite. No accurate thickness can be determined for the Otter Point Mélangé, but a most conservative estimate of the thickness within the study area, extrapolated from the cross-section (Figure 2), is in excess of 1100 meters (3600 feet).

The lower Eocene Roseburg Formation (Baldwin, 1974) overlies and is in fault contact with the Otter Point Formation. Rocks of the Roseburg Formation are predominantly massive sandstone. The Roseburg Basalt (Baldwin, 1974), common in areas to the north and east, is not present in the Bethel Creek - North Fork area. In the center of the study area, the thickness of the Roseburg Formation is at least 800 meters (2600 feet).

The uppermost unit in the section is the lower to middle Eocene Lookingglass Formation (Baldwin, 1974). Massive and channelled sandstone and massive conglomerate constitute the bulk of the Lookingglass Formation. Generally, the Lookingglass Formation overlies the Roseburg

Formation, but in section 29 (see Figure 1), the Lookingglass directly overlies the Otter Point Formation. The contacts between the Lookingglass and Otter Point Formations and between the Lookingglass and Roseburg Formations are depositional, with angular unconformities between all units. The thickness of the Lookingglass Formation, in the northern portion of the area, is estimated to be a minimum of 43 meters (140 feet). In section 29 (see Figure 1), the Lookingglass formation is only a meter or two thick, but thickens to perhaps 30 meters (100 feet) south of the study area (Bounds, in prep.).

ROCK UNITS

The bedrock units in the Bethel Creek - North Fork area are described here in order of decreasing age.

Otter Point Formation

Koch (1966) described the Otter Point Formation (type section) as follows:

The type section at Otter Point, in the NE. $\frac{1}{4}$ of sec. 13, T. 36 S., R. 15 W., Gold Beach Quadrangle, consists of repetitiously interstratified, dark gray to black, thin mudstone and graded sandstone, some pebbly mudstone, and several thin beds of andesitic and keratophyric volcanic breccia. The sandstone has convolute bedding, fine cross-stratification (amplitudes up to 3 cm.), and contortions, as well as groove, flute, and load sole marks. Some of the mudstone contains abundant coalified plant debris and numerous small lenses and nodules of very argillaceous limestone.

Within the Bethel Creek - North Fork area, rocks of

the Otter Point Formation are widely distributed, but poorly exposed. The Otter Point Mélange consists of three major rock types: matrix, native blocks, and exotic blocks. The matrix makes up over ninety percent of the Otter Point Mélange, with the native and exotic blocks making up about three and seven percent, respectively. The native and exotic blocks are distributed randomly throughout the matrix.

Matrix. The bulk of the Otter Point Formation is composed of rock herein referred to as matrix. This rock is pervasively sheared mudstone and argillite. The only exposures of the matrix are found in road cuts, excavations, and rarely, around large native and exotic blocks. Stream channels are generally too choked with vegetation to offer good exposures.

In fresh exposures, the matrix consists of thin discontinuous beds of argillite separated by pervasively sheared mudstone or claystone. Where fresh, the matrix is dark gray to black and weathers to a blue-gray. Thin sandstone laminae are present in some exposures. Veins and stringers of secondary quartz and calcite commonly cross-cut the bedding (cleavage). More weathered exposures of the matrix are characterized by blue-gray clay containing abundant angular fragments of argillite, quartz, and calcite.

Native Blocks. Numerous blocks of lithic sandstone

(graywacke), rhythmically bedded sandstone and shale (argillite), and pebble to cobble conglomerate are distributed throughout the Otter Point Formation. These rocks do not form continuous units, but are instead, isolated blocks "floating" in the surrounding matrix. Such blocks are herein referred to as native blocks because they are sedimentary and are probably related to the matrix. These rocks probably represent the coarse clastic component of the trench turbidite sequence (Connelly, 1978).

The native blocks range in size from a few meters to more than a kilometer in maximum dimension. The blocks generally form prominent outcrops as they are far more resistant than the matrix. Several ridges are supported by blocks of sandstone or conglomerate. The sandstone and conglomerate are medium gray to dark gray-green. Graded beds, sole marks, pebble lenses, and clay laminae are present in some blocks.

It would appear that the type section of the Otter Point Formation (Koch, 1966) describes one or more native blocks. This is due, probably, to the fact that the concept of *mélange* was, at best, poorly understood at that time. It was not until 1968 that K.J. Hsu published a paper dealing with the concept of *mélange* and its application to west coast geology.

In thin section, the native block sandstone varies from fine to coarse grained and the grains are angular to

Figure 6. Photomicrograph of a typical Otter Point sandstone. Shale clast is approximately two millimeters in length (plane polarized light).

sub-rounded (Figure 6). Quartz, plagioclase, and rock fragments are the major framework components. Included rock fragments comprise chert, argillite, and to a lesser extent, basalt and phyllite or schist. Trace amounts of sphene, epidote, hornblende, and opaques are also present. The matrix consists of clay and varying amounts of limonite and chlorite. The cement is silica or clay. Some of the sandstone is pervasively sheared; fractures filled with quartz, chlorite, or calcite are common.

One sample contains a significant amount of glaucophane as overgrowths on hornblende grains. The glaucophane seems to have formed after lithification, as it is intergrown with the matrix. This sample also contains pervasive intergrowths of apatite in the matrix, giving the rock a felted appearance in thin section. The presence of glaucophane and apatite indicates this sandstone has been subjected to a higher degree of metamorphism than other sandstones in the area (Deer, Howie, and Zussman, 1966). This, in turn, suggests deeper burial prior to emplacement within the mélangé.

Two large blocks of conglomerate are exposed along Bethel Creek Road in sections 18, 19, 20, and 21 (see Figure 1). Another smaller block is exposed below Langlois Mt. Road in sections 28 and 29 (see Figure 1). The conglomerate is composed of sandstone and chert pebbles and cobbles in a sandstone matrix (Figure 7). Within the

Figure 7. Photomicrograph of an Otter Point chert pebble conglomerate. Clasts are chert and about five millimeters in diameter. Note the radiolarian chert in the lower left (plane polarized light).

conglomerate, sandstone beds and lenses are common. The sandstone forming these beds and lenses is petrographically identical to the conglomerate matrix.

Although no megafossils were found in the Bethel Creek - North Fork area, fragments of ammonite and a few complete pelecypod valves (Buchia sp.) were found in argillites of a bedded sandstone and argillite block south of the study area, along Sixes River Road. Carbonaceous plant debris is present in some native blocks.

Exotic Blocks. The exotic block group comprises three distinct rock types. These are, in order of abundance, glaucophane schist, radiolarian chert, and metabasalt.

Glaucophane schist (blueschist) is the most abundant exotic rock type. The blocks of schist vary in size from a few meters to several hundreds of meters in diameter. Outcrops of the schist are dark green to dark blue-gray due to high concentrations of either actinolite or sodium amphibole (glaucophane).

The glaucophane schist usually exhibits well developed foliation and schistosity; gneissic (compositional) banding is present in some blocks. The schist is very resistant to chemical and mechanical weathering and commonly, blocks of schist form small knolls. Where present in large masses, the glaucophane schist is an excellent source of rock for jetties, breakwaters, and road fill.

Petrographically, the texture of the glaucophane

schist varies somewhat from sample to sample. Compositional banding, not evident megascopically, is common. All samples exhibit strong lineation of elongate-prismatic crystals (Figure 8). Foliation defined by mica crystals is evident in all samples except those that exhibit well developed gneissic structure.

Mineral composition is highly variable, but can be characterized by the assemblage - glaucophane (crossite), actinolite, epidote group (epidote, clinozoisite, and zoisite), with greater or lesser amounts of albite, quartz, chlorite, garnet (almandite?), muscovite, and trace amounts of sphene, apatite, rutile, and lawsonite. The variations in composition are presumably a function of source rock type and metamorphic grade. Possible source rocks include basalt and graywacke.

Porphyroblasts of garnet are common in most samples. these garnets appear euhedral (Figure 9a), but upon closer examination often exhibit partial replacement by chlorite (Figure 9b). This may be due to simple alteration or it may be an indication of retrograde metamorphism. Considering the deformational history of the Otter Point Formation and the retrograde metamorphism described by Coleman and Lanphere (1971), the latter seems quite probable.

Several blocks of bedded radiolarian chert occur within the study area. The blocks range in size from a few meters to a few tens of meters in diameter. Viewed from a

Figure 8. Otter Point glaucophane schist. Garnet porphroblasts are two millimeters in diameter (polarized light).

Figure 9a. Euhedral garnet porphroblast within the glaucophane schist (polarized light).

Figure 9b. Garnet porphroblast in Figure 9a in plane polarized light. Note the chlorite alteration (cl).

distance, outcrops of chert are reddish brown in color, due to high concentrations of iron and manganese oxides. Isolated masses of metabasalt are interbedded with the chert in some blocks.

The chert is rhythmically bedded, with minor interbeds of siliceous shale or argillite. The chert beds range in thickness from three to eight centimeters and the shale beds rarely exceed two centimeters in thickness. The color of the chert varies, not only from block to block, but also, within a single block. Common colors are red, yellow, and green, due to the oxidation state of incorporated iron. The intercalated shale is dark gray-green in color on fresh surfaces, but stained red by hematite on weathered surfaces.

Intense chevron or kink folding is common. The hinges of these folds do not exhibit appreciable thickening or fracturing. Small scale boudinage is common on the limbs of the folds.

In thin section, the chert consists of radiolarian tests in a matrix of cryptocrystalline to microcrystalline quartz and disseminated iron oxides (hematite, limonite, etc.) (Figure 10). One to three millimeter laminae are present in some beds. The laminae are defined by concentrations of radiolarian tests. Planes between laminae are clearly defined by concentrations of opaque grains. Fractures filled with mosaic quartz are numerous, commonly intersecting to give the chert a brecciated appearance.

Figure 10. Typical Otter Point radiolarian chert. Field of view is approximately five millimeters.

Well preserved radiolarian tests are found throughout the chert. Several shapes were noted, including sphere and cone (Figure 11). The tests are filled with mosaic quartz and do not contain appreciable amounts of iron oxide.

Blocks of metabasalt are not common in the Bethel Creek - North Fork area and are difficult to distinguish from native blocks, in the field. As with the other exotic rock types, there seems to be no pattern to the distribution of the metabasalt blocks. To the south however, metabasalt blocks are concentrated in a large east-west shear zone (Bounds, in prep.).

The metabasalt is medium gray to dark green in color and forms angular, rubbly outcrops. No relict structures were noted in the metabasalt within the study area, although outcrops in other areas do exhibit pillow structures. Although extensive elsewhere in the region (e.g. in the Sixes River drainage; Lent, 1969), no volcanic breccia was found in the Bethel Creek - North Fork area.

On the basis of thin section examination, the metabasalt is divided into two types: type I metabasalt is characterized by partial replacement of ferromagnesian minerals by chlorite, only slight alteration of plagioclase, and well preserved igneous texture; type II metabasalt is typically pervasively sheared and severely altered, primary igneous textures are poorly preserved, and glaucophane is present as overgrowths on hornblende.

Figure 11. Conical and spherical radiolaria within the radiolarian chert. Field of view is about 1.5 millimeters.

Type I metabasalt is massive, porphyritic, and slightly sheared; exhibiting well preserved sub-ophitic texture (Figure 12). Plagioclase (An_{50}), hornblende, and hypersthene are the major constituents; chlorite, epidote, quartz, and skeletal ilmenite are accessory. Chlorite forms reaction rims on hypersthene and hornblende and is associated with quartz in fracture fillings. Minor amounts of serpentine form pseudomorphs of euhedral olivine phenocrysts. Epidote occurs in the groundmass and is attributable to alteration of groundmass plagioclase.

Type II metabasalt is massive and pervasively sheared. Severe alteration has all but obliterated the primary igneous texture (Figure 13). It appears the type II rock was a glassy, porphyritic basalt. A few phenocrysts of spil-litized plagioclase and hornblende remain in a groundmass of epidote, apatite, and quartz. Fractures filled with quartz and chlorite are common.

Most of the hornblende exhibits overgrowths of glaucophane and partial alteration to chlorite. The phenocrysts of plagioclase (An_{15}) typically exhibit strain twinning. The groundmass has a felted appearance due to extensive intergrowths of acicular apatite. The degree of shearing and the presence of glaucophane and apatite suggest a much higher grade of metamorphism for type II metabasalt than for type I.

Figure 12. Photomicrograph of type I metabasalt. White - plagioclase, gray - hypersthene and chlorite. Field of view is about five millimeters (polarized light).

Figure 13. Photomicrograph of type II metabasalt. Note the pervasive shearing. Field of view is about five millimeters.

Roseburg Formation

Rocks of the Roseburg Formation make up about 80 percent of the Tertiary rocks within the Bethel Creek - North Fork area. The Roseburg Formation is exposed in two north trending belts; one along the western margin of the area and one through the center of the area (see Figure 1). Baldwin (1973) described the typical Roseburg sedimentary rocks as follows:

Sedimentary rocks within the Roseburg Formation include thick sections of rhythmically bedded sandstone and siltstone, ..., and minor amounts of conglomerate and pebbly sandstone.

Within the Bethel Creek - North Fork area, this description is not applicable. The principle rock type within the study area is massive, fine to medium grained sandstone. North trending lenses and thin beds of chert pebble conglomerate and pebbly sandstone occur sporadically within the sandstone. Sequences of rhythmically bedded sandstone and siltstone are not common.

Thin section examination indicates the Roseburg sandstone is a massive, clay cemented lithic sandstone. The sandstone is fine to medium grained, moderately well sorted with sub-rounded grains. The framework constituents are rock fragments, quartz, and plagioclase (Figure 14). The lithic component comprises chert, metamorphic and volcanic rock fragments.

Figure 14. Photomicrograph of a typical Roseburg Formation sandstone. White and gray - quartz and plagioclase, black - rock fragments. Field of view is about five millimeters (polarized light).

Lookingglass Formation

Rocks of the Lookingglass Formation are not widespread within the Bethel Creek - North Fork area. They occur in section 29, along Langlois Mt. Road and in sections 11, 12, and 14, along the northern boundary of the area (see Figure 1).

Baldwin (1973) described the Lookingglass Formation as follows:

The Lookingglass Formation consists of a thick marine sequence of rhythmically bedded, fine grained sandstone and siltstone and a prominent basal near-shore sequence of conglomerate and massive sandstone.

Within the study area, the Lookingglass Formation consists of massive, medium to coarse grained sandstone, channelled and cross-bedded sandstone exhibiting graded coarse grained pebbly sandstone and conglomerate lenses and channels, massive to thick bedded conglomerate, and minor rhythmically bedded sandstone and mudstone sequences. Clasts within the conglomerate consist of plutonic and extrusive igneous rocks, chert, and sandstone.

In thin section, the Lookingglass sandstone is medium to coarse grained, poorly sorted, and clay cemented; the grains are angular to sub-rounded (Figure 15). Framework grains include igneous rock fragments, quartz, and plagioclase.

Figure 15. Photomicrograph of a typical Lookingglass Formation sandstone. White and gray - quartz and plagioclase, black - rock fragments. Field of view is about five millimeters (polarized light).

STRUCTURAL GEOLOGY

Structure in the Bethel Creek - North Fork area is expectably complicated. Structural styles are generally consistent within continuous units, but differ markedly from unit to unit (e.g. Otter Point - Roseburg, Roseburg west - Roseburg east). On the basis of the differing structural styles, structural units are designated as follows: Mélangé Terrane, North Fork Block, and Morton Creek Block (Figure 16).

Mélangé Terrane

The Mélangé Terrane, which includes all of the Otter Point Formation, is characterized by chaotic folding and pervasive, small scale shearing, as well as widespread distribution of tectonically emplaced exotic blocks.

Due to the incompetent nature of the matrix, which forms most of the volume of the Otter Point Formation, few faults can be traced or even identified. This is not to say faults are not common in the Otter Point; they are probably ubiquitous, or more properly, deformation grades from locally discontinuous to generally continuous. Major faults or fault zones are usually defined by linear bodies of serpentinite, but smaller faults are simply lost in the regional shearing. The incompetent nature of the matrix also makes any structural data taken from the matrix subject to question. Most exposures of matrix exhibit signs of

significant slumping.

Structural analysis of the Otter Point Formation has been limited to the native blocks, which, for the most part, do not exhibit the severe deformation or slumping characteristic of the matrix. Graded beds and channels within the native blocks indicate the blocks are not presently overturned.

The π -s to bedding diagram (Figure 17), from native blocks in the western belt of Otter Point M $\acute{e}$ lange, shows two well defined point maxima which indicate two planar preferred orientations (Turner and Weiss, 1963); the principle orientation is 290° 20 NE. and the second orientation is 045° 20 SE. The β intersection diagram of the same data shows two fold axes; the principle axis trends 090° and plunges 10° and the secondary axis trends 348° and plunges 25° . The point maxima define a great circle girdle which implies most of the intersections lie in a plane that strikes approximately 089° and dips 25° NW. This suggests multiple folding events which is consistent with the structure of a melange (Figure 18).

The π -s diagram from native blocks in the eastern belt of Otter Point M $\acute{e}$ lange (Figure 19) exhibits a point maximum indicating a preferred orientation of 045° and dips of 35° to 65° SE. The β intersection diagram of the same data (Figure 20) two coalescing point maxima representing two sub-parallel fold axes; one trending 225° and plunging

Figure 17. Contoured π -s diagram of bedding planes from native blocks within the Western Belt - Mélange Terrane; contours at 10, 20, 30, and 40 percent per one percent area, 10 points.

Figure 18. Contoured β intersection diagram of bedding planes from native blocks within the Western Belt - Mélange Terrane; contours at 2, 6, 8, 13, and 20 percent per one percent area, 45 points.

Figure 19. Contoured π -s diagram of bedding planes from native blocks within the Eastern Belt - Mélange Terrane; contours at 12, 25, and 35 percent per one percent area, 8 points.

Figure 20. Contoured β intersection diagram of bedding planes from native blocks within the Eastern Belt - Mélange Terrane; contours at 3, 7, 10, 14, and 16 percent per one percent area, 28 points.

20°, the other trending 245° and plunging 28°. Although this pattern is somewhat different from the pattern of the western belt, the style of deformation is similar; therefore, both the western and eastern belts are herein considered to be within the same structural unit. The difference in pattern can be explained by separating the eastern and western belts by a fault. A later discussion of mélangé morphology will better explain the presence of this fault.

North Fork Block

The North Fork Block (NFB) includes the Roseburg and Lookingglass Formations in the central portion of the Bethel Creek - North Fork area (see Figure 1). The NFB is bounded on the east and west by north trending faults which form the contacts between the Roseburg Formation and the surrounding Otter Point Mélangé.

A π -s diagram of data from the Roseburg Formation within the NFB (Figure 21) shows a great circle girdle; the pole of this girdle defines a north-south fold axis. The β intersection diagram of the same data exhibits a prominent north-south fold axis (Figure 22). Field observation shows this fold axis to be the axis of a north trending, gently plunging syncline. A minor east-west axis is also suggested and is probably the expression of a later folding event.

A large anticlinal drag fold is present along the

Figure 21. contoured π -s diagram of bedding planes in the Roseburg Formation within the North Fork Block; contours at 3, 7, 11, and 18 percent per one percent area, 27 points.

Figure 22. Contoured β intersection diagram of bedding planes in the Roseburg Formation within the North Fork Block; contours at $\frac{1}{2}$, 3, 5, 10, 15, and 20 percent per one percent area, 351 points.

western margin of the North Fork Block. The axis of this fold roughly parallels the trend of the western boundary fault. This drag fold indicates the motion on the boundary fault was such that the NFB moved up relative to the surrounding Otter Point Melange. The eastern margin of the NFB may also exhibit a drag fold, although poor exposures make this difficult to determine.

Faulting within the NFB is confined to normal faulting. The faults are concentrated on the eastern side of the block (see Figure 1) and suggest an extensional regime, as opposed to the compressional regime, suggested by the drag fold, for the western side of the NFB. These normal faults may also explain the lack of a well developed drag fold along the eastern margin of the North Fork Block.

Due to the similarity of structural styles, rocks of the Lookingglass Formation are included within the North Fork Block. The π -s diagram of data from the Lookingglass Formation (Figure 23) has a point maximum very close to the center of the diagram. This indicates the Lookingglass Formation has undergone only slight deformation. The β diagram of the same data (Figure 24) exhibits two well developed fold axes; the principle axis trending 110° and plunging 15° and a secondary axis trending 340° and plunging 10° . The secondary axis is approximately parallel to the axis of the syncline expressed in the underlying Roseburg Formation. The principle axis is similar to the east-west

Figure 23. Contoured π -s diagram of bedding planes in the Lookingglass Formation within the North Fork Block; contours at 6, 13, 20, and 26 percent per one percent area, 15 points.

Figure 24. Contoured β intersection diagram of bedding planes in the Lookingglass Formation within the North Fork Block; contours at $\frac{1}{2}$, 3, 6, and 11 percent per one percent area, 105 points.

axis of the underlying Roseburg. Both of these east-west axes are probably due to the same folding event. This event probably took place after the deposition of the Lookingglass Formation.

Morton Creek Block

The Morton Creek Block (MCB) consists only of rocks of the Roseburg Formation. The MCB was separated from the North Fork Block on the basis of markedly differing structural style. The structure of the MCB is influenced by a large shear zone which forms the eastern boundary between the Morton Creek Block and the Mélange Terrane. The π -s diagram (Figure 25) shows no apparent preferred orientation. The β intersection diagram (Figure 26) exhibits three fold axes; a principle axis trending 160° and plunging 25° , a secondary axis trending 265° and plunging 10° , and a third axis trending 025° and plunging 12° . These fold axes differ greatly from those within the North Fork Block, although some similarity exists between the east-west axes in both blocks.

The shear zone between the MCB and the Mélange Terrane is herein interpreted as a left lateral strike-slip fault. This motion is supported by truncation of east-west shear zones and southward deflection of exotic block "trains" to the south of the Bethel Creek - North Fork area (Bounds, in prep.). The Morton Creek Block developed as a "fault slice" of the North Fork Block displaced southward along the

Figure 25. Contoured π -s diagram of bedding planes within the Morton Creek Block; contours at 11, 22, and 33 percent per one percent area, 9 points.

Figure 26. Contoured β intersection diagram of bedding planes within the Morton Creek Block; contours at 2, 5, 8, and 10 percent per one percent area, 36 points.

shear zone. This left lateral motion explains the east-west fold axes in both the Morton Creek and North Fork Blocks. This fault must, at least in part, be younger than the lower Eocene Roseburg Formation and is certainly younger than the lower to middle Eocene Lookingglass Formation. No more can be determined about the age of the fault, except that Pleistocene terrace deposits do not seem to be displaced by it (these units were examined south of the study area).

CONCLUSIONS

Structural analysis within the Otter Point Formation is very difficult. Little, if any, usable data can be obtained from the matrix in the Bethel Creek - North Fork area. Data collected from native blocks, while reliable, may not be entirely representative of the structure of the Otter Point Formation. For these reasons, only a limited structural analysis was performed on the Otter Point Formation.

Structural data from native blocks suggest several deformational events. Most of these events probably occurred during the formation of the *mélange*, although the π -s and β diagrams from the western belt of Otter Point do show axes, similar to the axes in the overlying Tertiary rocks, that could be attributed to the movement of the left lateral fault. The outcrop pattern of the native blocks in the western belt is somewhat linear and may represent a dismembered channel within the Otter Point Formation. No other evidence is available to support this, however. Figure 27 is a sketch map of this outcrop pattern. The westward deflection of the northern end of the "train" of native blocks may be the result of drag along the fault.

As shown in the discussion of structural geology, structural and stratigraphic data support the synclinal

Figure 27. Sketch map of sections 16, 17, 18, 19, 20, 21, 28, 29, and 30, T. 30 S., R. 14 W., showing the distribution and outcrop pattern of native blocks within the Western Belt - Mélange Terrane (see Figure 1). Tcmb - Morton Creek Block, Jwb - Western Belt - Mélange Terrane, Tnfb - North Fork Block; dashed line indicates the extent of the native block "train".

structure of the Roseburg and Lookingglass Formations (within the North Fork Block) described by Phillips (1968). As shown in Figure 1, the axial trace of the syncline is slightly arcuate and plunges gently to the north. The faults bounding the North Fork Block and the structure (drag fold) within the Roseburg Formation adjacent to the faults suggest that the NFB moved up relative to the surrounding Otter Point Formation. This interpretation is not consistent with previous mapping (Phillips, 1968; Brownfield, 1972). To explain this interpretation, the following hypothesis is offered.

The Otter Point Mélange was initially deposited as turbidites (Connelly, 1978) in a trench formed by the intersection of the Farallon (Kula?) plate with the North American plate. From paleontologic and radiometric dates (Koch, 1966; Lent, 1969; Coleman and Lanphere, 1971), it would appear this deposition and subsequent deformation took place in the late Jurassic, although a larger time span would not be inconsistent with the depositional and deformational histories of other mélange complexes (the Franciscan of California and the Argille Scagliosa of Italy; Bailey, 1964; Maxwell, 1970). A schematic cross-section through the "Farallon" trench is shown in Figure 28. With continued subduction, the trench turbidites are deformed into wedges (lobes) bounded by shoreward steepening thrust faults. The wedges consist of pervasively sheared

Figure 28. Schematic cross-section through the "Farallon" trench (modified from Connelly, 1978).

and folded turbidite material, some blocks of lesser deformed turbidite, blocks of basalt and chert derived from the subducted slab, masses of previously formed *mélange* material slumped back into the trench, and blocks of glaucophane schist (blueschist) and associated rock types presumably carried (rafted) up along shear zones. The distance from the crest of one wedge to the crest of the next is about five kilometers. This is supported by seismic reflection profiles across modern accreting margins (Carson, 1974). Small linear basins between wedges could have remained structural lows long after their formation. To the south of the Sixes River, these basins may have controlled the deposition of Cretaceous sediments (Bourgeois, pers. comm., 1980). To the east, in the area of Agness, the linearity of the Tertiary exposures suggests the same may be true (Figure 29). The linearity of the North Fork Block may also be explained in this way.

A structural low between two *mélange* wedges served to channel Tertiary sediments (Roseburg Fm.) to the north (Figure 30). These sediments were deposited directly on the Otter Point *Mélange*, in the Bethel Creek - North Fork area, but may overlies Cretaceous rocks to the north. During deposition of the Roseburg Formation, continued east-west compression downwarped the sediments into a gently plunging, north trending syncline. Further compression caused the more competent Roseburg rocks to slide upward along the con-

Figure 29. Sketch map showing the Tyee and South Slough Basin feeder channels (modified from Ramp, 1969).

Figure 30. Hypothetical east-west cross-section through the North Fork Block depositional "basin" at the time of Roseburg Formation deposition.

tacts with the less competent melange (Figure 31). Assuming an asymmetrical basin (Figure 32), the west side of the block was allowed to slide upward more than the east side. This would put a portion of the block in tension. The normal faults in the eastern part of the North Fork Block and the smaller or nonexistent drag fold along the eastern margin of the block seem to support this. In other words, the western side of the block moved up and west to a greater extent than the eastern side moved up and east. Due to the plastic nature of the Otter Point Mélange (matrix), the block was supported as it moved by material flowing into the "void" created by the movement.

Near the end of this compressive event, Lookingglass sediments were deposited along the axis of the syncline. Due to the relative uplift of the block or overfilling of the basin, some of the Lookingglass sediments were deposited directly on the marginal Otter Point Mélange (see Figure 1). The lesser degree of deformation in the Lookingglass rocks indicates only slight east-west compression during or after deposition.

After deposition of the Lookingglass Formation, the North Fork Block was dismembered by a left lateral fault to form the Morton Creek Block. East-west fold axes in both the North Fork and Morton Creek Blocks and the anticlinal structures in the Morton Creek Block (Brownfield, 1972) and the lithologic similarity between the blocks suggest that

Figure 31. Hypothetical cross-section through the North Fork Block "basin" with renewed movement on the mélangé wedge thrust fault.

Figure 32. Hypothetical cross-section through the North Fork Block showing the development of normal faults.

both blocks could have been one larger block dismembered in this manner.

REGIONAL SIGNIFICANCE

As previously shown, deposition of the Roseburg and Lookingglass Formations, within the Bethel Creek - North Fork area, occurred in structurally controlled, linear basins formed between wedges of Otter Point Mélange. On a regional scale, these basins served to channel sediments from sources to the south to larger depositional basins to the north (see Figure 29). At least two channels fed the eastern portion of the Tyee Basin (Perttu, pers. comm., 1981); another channel, the South Slough Channel, fed the western portion of the Tyee Basin. Continued compression along the accreting continental margin caused selective uplift of some of the mélange wedges (Figure 33) such that continuity of sedimentation across the Tyee Basin was blocked, at the end of the deposition of the Elkton Siltstone. The western portion of the Tyee Basin, now referred to as the South Slough Basin, will be the topic of the remainder of this discussion.

Units within the South Slough Basin include the Coaledo, Bastendorff, Tunnel Point, "Tarheel", and Empire Formations. The upper Eocene Coaledo Formation consists of three members; the lower and upper members are predominantly deltaic sandstone, whereas, the middle member is

Figure 33. Tyee Basin before development of South Slough Basin (A.) and after movement along mélangé wedge faults (B.).

predominantly thin bedded mudstone (Baldwin and others, 1973). A thickness of 1800 meters (6000 feet) is reported by Baldwin (1973). Conformably overlying the Coaledo Formation, the uppermost Eocene Bastendorff Formation consists of more than 600 meters (2000 feet) of thin bedded shale (Baldwin and others, 1973). Conformably overlying the Bastendorff Formation is the lower Oligocene Tunnel Point Formation; 240 meters (800 feet) of fine to coarse grained, 'current sorted' sandstone (Baldwin and others, 1973). Only eight meters (26 feet) of the middle Miocene "Tarheel Formation" (Armentrout, 1967) sandstone and conglomerate are exposed (at low tide) within the South Slough Basin (Baldwin and others, 1973). The contact between the Tunnel Point and "Tarheel" Formations is probably unconformable. The Pliocene Empire Formation unconformably overlies the Tunnel Point and "Tarheel" Formations. The Empire Formation consists of 500 meters (1600 feet) of feldspathic graywacke and siltstone (Baldwin and others, 1973).

These units suggest fairly continuous deposition in a tectonically active basin. Deposition specific to the South Slough Basin began with the building of the lower Coaledo delta by sediment being fed to the delta through the South Slough Channel. Basin subsidence accompanying continued development of the wedges in the underlying Otter Point Mélange changed the lower Coaledo shallow water environment to a somewhat deeper water environment con-

sistant with the deposition of the middle Coaledo mudstone. As the South Slough Basin filled with middle Coaledo mudstone, the upper Coaledo delta began to prograde northward into the basin. This is supported by the thickening of the middle Coaledo northwestward (Baldwin and others, 1973).

Renewed subsidence again changed the environment of deposition from shallow to deeper water, and deposition of the Bastendorff Formation shale occurred over the upper Coaledo. Again the basin filled and channel(?) deposits of the Tunnel Point Formation, similar to those of the Roseburg Formation in the Bethel Creek - North Fork area, were deposited over the Bastendorff Formation.

By this time, each successive episode of subsidence had narrowed the basin to the point that deposition of the Miocene and Pliocene sandstones was limited to a narrow strip along the axis of the basin. The lack of angular unconformities between the members of the Coaledo Formation and the Bastendorff and Tunnel Point Formations can be explained in the following way: the South Slough Basin was wide enough that, in the initial stages, the deformation associated with subsidence only effected the margins of the basin. By the time of deposition of the Empire Formation, the repeated subsidence and filling of the basin had narrowed it to the extent that even rocks within the center of the basin were deformed by the subsidence.

In conclusion, the Tyee and South Slough Channels are

very similar in orientation and lithology. The Tyee and South Slough "deltas" are similar and, initially, were part of the same basin. Depositional activity in the Tyee basin, at least in the southern part, had essentially ended at or about the time that deposition, specific to the South Slough Basin, began. The north-south orientation of both the Tyee and South Slough Basins was controlled, in part, by the presence of the Canyonville - Sixes River Fault Zone and, in part, by the north-south linearity of the Otter Point Mélange complex, on which the basins formed. The present structure within both the Tyee and South Slough Basins, alternating, north-south trending anticlines and synclines, supports the hypothesis that these basins formed on and were controlled by the tectonically active Otter Point Mélange.

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APPENDIX A

COMPUTER PROGRAMS FOR STRUCTURAL ANALYSIS

A Pi (π) diagram is a diagram constructed on an equal area net from the projections of poles (lines) perpendicular to planes (bedding planes, foliation planes, etc.). The poles plot as points on the diagram (Billings, 1972).

The program PIPLOT is a FORTRAN program for the reduction and plotting of structural data as Pi diagrams. The program was developed by J. Warner (1968) and, although substantial modifications have been made, the principle logic has not been altered.

The program reduces field or laboratory observations into unit vectors representing points on the sphere, enters this data into a three dimensional matrix, performs a population density count on the matrix, compresses the matrix into a two dimensional array, and prints out a contoured diagram.

Input on title and control card:

<u>COLUMN</u>	<u>INPUT</u>	<u>EXPLANATION</u>
2	0	end of data flag
2	1	point plot option (no contours)
2	2	contoured plot option
4	1	linear data (also output from <u>BETACAL</u>)

<u>COLUMN</u>	<u>INPUT</u>	<u>EXPLANATION</u>
4	2	quadrant planer data
4	3	azimuthal planer data
4	4	normal elements on u-stage
4	5	parallel elements on u-stage
6-8		number of data sets
9-80		title for identification of diagram

Input on data cards:

5-10	strike	quadrant strike (e.g. N40. W)
15-19	dip	dip and dip direction (e.g. 35. E)
6-9	strike	azimuthal strike (e.g. 340.)
14-18	dip	dip and dip direction (e.g. 35. E)

Several sets of data may be run by stacking the data sets (control and data cards). The last card in the data stack must be an end of data flag; a card with a zero in column two.

PROGRAM LISTING

```

01C   ***   PROGRAM PILOT   ***
02C   STERO-NET POINT COUNT AND ROTATION PROGRAM
03C   LISTING OF THE POINT COUNT PROGRAM
04C   VERSION 5   NASA-MSC UNIVAC 1108
05C   OCT. 24, 1968
06C   BY JEFFREY WARNER
07C   MODIFIED BY DAVID SCOFIELD MAR. 1972
08C   MODIFIED BY C. FRED GULLIXSON JAN. 09, 1979 FOR HARRIS 220
09C   FURTHER MODIFICATION OCT. 1979 FOR HONEYWELL 66\20
10C
11   INTEGER ID17, ID26, ID31, ID35, ID1, ID2
12   INTEGER T, S, INDEX, IND, N, Q
13   DIMENSION JM(75), IM(75), AZC(1250), ROEC(1250), DUMMY(40)
14   DIMENSION XV(1250), YV(1250), ZV(1250), CTPC(57,95), TITLE(72)
15   COMMON AZC, ROEC, T, S, N
16   DATA JM(1), JM(2), JM(3), JM(4), JM(5)/95, 1, 48, 48, 48/
17   DATA JM(6), JM(7), JM(8), JM(9), JM(10), JM(11), JM(12), JM(13),
18%   JM(14), JM(15), JM(16), JM(17), JM(18), JM(19), JM(20), JM(21),
19%   JM(22), JM(23), JM(24), JM(25), JM(26), JM(27), JM(28), JM(29),
20%   JM(30), JM(31), JM(32), JM(33), JM(34), JM(35), JM(36), JM(37),
21%   JM(38), JM(39), JM(40), JM(41), JM(42), JM(43), JM(44), JM(45),
22%   JM(46), JM(47), JM(48), JM(49), JM(50), JM(51), JM(52), JM(53),
23%   JM(54), JM(55), JM(56), JM(57), JM(58), JM(59), JM(60), JM(61),
24%   JM(62), JM(63), JM(64), JM(65), JM(66), JM(67), JM(68), JM(69),
25%   JM(70), JM(71), JM(72), JM(73), JM(74), JM(75)/47, 46, 45, 44,
26%   43, 42, 41, 40, 39, 38, 37, 36, 35, 34, 33, 32, 31, 30, 29, 28, 27,
27%   26, 25, 24, 23, 22, 21, 20, 19, 18, 17, 16, 15, 14, 13, 12, 11,
28%   10, 9, 8, 7, 6, 5, 4, 3, 2, 1, 1, 1, 1, 1, 1, 1, 2, 1, 0/
29   DATA IM(1), IM(2), IM(3), IM(4), IM(5), IM(6), IM(7), IM(8), IM(9),
30%   IM(10), IM(11), IM(12), IM(13), IM(14), IM(15), IM(16), IM(17), IM(18),
31%   IM(19), IM(20), IM(21), IM(22), IM(23), IM(24), IM(25), IM(26),
32%   IM(27), IM(28), IM(29), IM(30), IM(31), IM(32), IM(33), IM(34),
33%   IM(35), IM(36), IM(37), IM(38), IM(39), IM(40), IM(41), IM(42),
34%   IM(43), IM(44), IM(45), IM(46), IM(47), IM(48), IM(49), IM(50),
35%   IM(51), IM(52), IM(53), IM(54), IM(55), IM(56), IM(57), IM(58),
36%   IM(59), IM(60), IM(61), IM(62), IM(63), IM(64), IM(65), IM(66),
37%   IM(67), IM(68), IM(69), IM(70), IM(71), IM(72), IM(73), IM(74),
38%   IM(75)/29, 29, 29, 57, 1, 1, 1, 1, 1, 1, 1, 1, 1, 1, 2, 2, 2, 2, 2, 2,
39%   3, 3, 3, 3, 4, 4, 4, 4, 5, 5, 5, 5, 6, 6, 6, 7, 7, 8, 8, 9, 10, 10, 11, 11,
40%   12, 12, 13, 13, 14, 15, 16, 16, 17, 17, 18, 19, 20, 21, 22, 22, 23,
41%   24, 24, 25, 26, 27, 28, 1, 1, 2, 0/
42   DATA (DUMMY(I), I=1, 40)/1H , 1H0, 1H1, 1H2, 1H3, 1H4, 1H5, 1H6, 1H7,
43%   1H8, 1H9, 1HA, 1HB, 1HC, 1HD, 1HE, 1HF, 1HG, 1HH, 1HI, 1HJ, 1HK, 1HL,
44%   1HM, 1HN, 1HO, 1HP, 1HQ, 1HR, 1HS, 1HT, 1HU, 1HV, 1HW, 1HX, 1HY, 1HZ,
45%   1H*, 1H+, 1H+/
46   DATA DIFLI/0.159/
47   DATA ID17, ID26, ID31, ID35, ID1, ID2/1HE, 1HN, 1HS, 1HW, 1HR, 1HL/
48C   S IS THE GENERAL READ CARD
49C   T IS THE GENERAL WRITE CARD
50   ACOS(A)=ATAN(SQRT(ABS(1-A*A)))/A)
51   T=23
52   S=22
53 2500 READ(S, 2501) INDEX, IND, N, (TITLE(Q), Q=1, 72)
54 2501 FORMAT(1X, I1, 1X, I1, 1X, I3, 1X, 72A1)
55   IF (INDEX=0) 998, 101, 998
56 998 WRITE (T, 115) (TITLE(Q), Q=1, 72), N
57 115 FORMAT (1H1, 5X, 72A1 /// 5X, I4, 14H OBSERVATIONS///)
58 116 GO TO (777, 125, 130, 134, 138, 142, 143, 144), IND

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59 777 CALL POLE1 (ID26,ID31,ID35)
60     GO TO 173
61 125 CALL POLE2 (ID17,ID26,ID31,ID35)
62     GO TO 173
63 130 CALL AZMUTH (ID17,ID26,ID31,ID35)
64     GO TO 173
65 134 CALL USTAG (IND,ID1)
66     GO TO 173
67 138 CALL USTAG (IND,ID1)
68     GO TO 173
69 142 CALL ROTE (IND,ID17,ID35)
70     GO TO 173
71 143 CALL ROTE (IND,ID17,ID35)
72     GO TO 173
73 144 IF (IND-8) 173,172,171
74 172 READ (S,160) (AZC(I),ROEC(I),I=1,N)
75 160 FORMAT (2F10.6)
76     WRITE (T,174)
77 174 FORMAT (5X,49HDATA IS AZIMUTH AND ROE FROM PREVIOUS CALCULATION///
78&      5X,20HDATA READ FROM CARDS///)
79     GO TO 173
80 171 CONTINUE
81     READ (S,160) (AZC(I),ROEC(I),I=1,N)
82     WRITE (T,175)
83 175 FORMAT (5X,49HDATA IS AZIMUTH AND ROE FROM PREVIOUS CALCULATION///
84&      5X,20HDATA READ FROM TAPE ///)
85 173 DO 106 I=1,N
86     ROSIN=SIN(ROEC(I))
87     XV(I)=SIN(AZC(I))*ROSIN
88     YV(I)=COS(AZC(I))*ROSIN
89     ZV(I)=COS(ROEC(I))
90 106 CONTINUE
91     XN=N
92     IF (INDEX-1) 5052,5051,5052
93 5051 WRITE(T,3500)
94 3500 FORMAT(' ','THIS WILL BE A POINT PLOT SHOWING POPULATION
95&      PERCENTAGE')
96 5052 WRITE(T,3501)
97 3501 FORMAT(' ','THIS WILL BE A CONTOURED POPULATION DENSITY PLOT')
98     IF (INDEX-1) 107,102,107
99 107 DO 330 I=1,57
100C     LONG VERSION OF ROUTINE TO PERFORM POINT COUNT AND FILL THE
101C         CTPC MATRIX WITH THE PERCENT POPULATION PER UNIT AREA
102     YI=(58-I)*2-58
103     YI=YI*0.01785714
104     DO 330 J=1,95,2
105     XI=J*2-96
106     XI=XI*0.01063829
107     COUNT=0.0
108     RAD=SQRT(XI*XI+YI*YI)
109     IF (RAD.GT.1.01) GO TO 331
110     AZ=ATAN2(XI,YI)
111     ROE=ATAN(RAD)*2.0
112     ZP=COS(ROE)
113     ROSN=SIN(ROE)
114     XP=SIN(AZ)*ROSN
115     YP=COS(AZ)*ROSN
116     DO 332 K=1,N

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117      DOTP=ABS(XV(K)*XF+YV(K)*YP+ZV(K)*ZF)
118      ANG=ACOS(DOTP)
119      IF (ANG-DIFLI) 121,121,332
120 121  COUNT=COUNT+1.0
121 332  CONTINUE
122 331  CTPC(I,J)=COUNT*100.0/XN
123 330  CONTINUE
124      GO TO 104
125 102  DO 776 I=1,N
126C      SHORT VERSION OF ROUTINE TO PERFORM POINT COUNT AND FILL THE CTPC
127C      MATRIX WITH PERCENT POPULATION PER UNIT AREA
128      RAD=(SIN(ROEC(I)/2.0))/(COS(ROEC(I)/2.0))
129      X=RAD*SIN(AZC(I))*142.5+142.5
130      Y=RAD*COS(AZC(I))*142.5+142.5
131      COUNT=0.0
132      DO 301 J=1,N
133      DOTP=ABS(XV(I)*XV(J)+YV(I)*YV(J)+ZV(I)*ZV(J))
134      ANG=ACOS(DOTP)
135      IF (ANG-DIFLI) 123,123,301
136 123  COUNT=COUNT+1.0
137 301  CONTINUE
138      COTPC=COUNT*100.0/XN
139      K=58.0-Y*0.2
140      M=X*0.333333+0.5
141      IF (K-1) 177,178,178
142 177  K=1
143 178  IF (M-1) 179,181,181
144 179  M=1
145 181  IF (COTPC-CTPC(K,M)) 776,776,182
146 182  CTPC(K,M)=COTPC
147 776  CONTINUE
148 104  CONTINUE
149C      PUT CIRCLE ONTO CTPC MATRIX
150      XXX=-999.9
151      DO 150 I=1,5
152      K=IM(I)
153      M=JM(I)
154      IF (CTPC(K,M).LE.0.0) CTPC(K,M)=XXX
155 150  CONTINUE
156      DO 151 I=6,74
157      I1=IM(I)
158      I2=58-I1
159      J1=JM(I)
160      J2=96-J1
161      IF (CTPC(I1,J1).LE.0.0)CTPC(I1,J1)=XXX
162      IF (CTPC(I1,J2).LE.0.0)CTPC(I1,J2)=XXX
163      IF (CTPC(I2,J2).LE.0.0)CTPC(I2,J2)=XXX
164      IF (CTPC(I2,J1).LE.0.0)CTPC(I2,J1)=XXX
165 151  CONTINUE
166C      ROUTINE TO CONVERT CTPC MATRIX FROM NUMERICAL VALUES TO PRINT
167C      SYMBOLS
168      DO 812 I=1,57
169      DO 812 J=1,95
170      IF (CTPC(I,J).LE.(-999.9)) GO TO 814
171      IF (CTPC(I,J).LE.0.0) GO TO 810
172      IF (CTPC(I,J).LE.0.5) GO TO 811
173      M=3
174 813  MM=M-2

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175      XMM=MM
176      IF (CTPC(I,J).LT.XMM) GO TO 815
177      M=M+1
178      IF (M.LE.37) GO TO 813
179      CTPC(I,J)=DUMMY(38)
180      GO TO 812
181 815 CTPC(I,J)=DUMMY(M)
182      GO TO 812
183 814 CTPC(I,J)=DUMMY(39)
184      GO TO 812
185 810 CTPC(I,J)=DUMMY(1)
186      GO TO 812
187 811 CTPC(I,J)=DUMMY(2)
188 812 CONTINUE
189C     PRINT AND ZERO MATRIX
190     WRITE (T,110)
191 110  FORMAT (1H1,51X,1H*)
192     DO 111 I=1,57
193     WRITE (T,112) (CTPC(I,J),J=1,95)
194 112  FORMAT (5X,95A1)
195     DO 111 J=1,95
196     CTPC(I,J)=0.0
197 111  CONTINUE
198     GO TO 2500
199 101  CONTINUE
200     CALL PRT1 (DUMMY)
201     STOP
202     END
203     SUBROUTINE POLE1 (ID26,ID31,ID35)
204C     LISTING OF THE LINEATION CONVERSION SUBROUTINE
205C     ROUTINE FOR LINEATION DATA
206     INTEGER ID26,ID31,ID35
207     INTEGER T,S
208     DIMENSION AZC(1250),ROEC(1250)
209     COMMON AZC,ROEC,T,S,N
210     T=23
211     S=22
212     WRITE (T,201)
213 201  FORMAT(5X,19HDATA ARE LINEATIONS/1H1,3X,6HSTRIKE,4X,6HPLUNGE///)
214     DO 202 I=1,N
215     READ (S,200) ISDR,ST,ISD,DIP
216     WRITE (T,200) ISDR,ST,ISD,DIP
217 200  FORMAT (3X,A1,F3.0,1X,A1,F8.0)
218     ROEC(I)=(90.0-DIP)*0.01745332
219     AZ=ST
220     IF (ISDR-ID31) 270,275,270
221 275  AZ=180.0-ST
222 270  IF (ISD-ID35) 281,280,281
223 280  AZ=180.0+ST
224 281  IF (ISD-ID35) 284,282,284
225 282  IF (ISDR-ID26) 284,283,284
226 283  AZ=360.0-ST
227 284  AZC(I)=AZ*0.01745332
228 202  CONTINUE
229     RETURN
230     END
231     SUBROUTINE POLE2 (ID17,ID26,ID31,ID35)
232C     LISTING OF THE PLANES CONVERSION SUBROUTINE

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233C    ROUTINES FOR PLANES DATA
234    INTEGER ID17,ID26,ID31,ID35
235    INTEGER T,S
236    DIMENSION AZC(1250), ROEC(1250)
237    COMMON AZC,ROEC,T,S,N
238    T=23
239    S=22
240    WRITE (T,220)
241 220  FORMAT (5X,15HDATA ARE PLANES/' ',3X,6HSTRIKE,7X,3HDIP///)
242    DO 221 I=1,N
243    READ (S,222) ST,ISD,DIP,IDPD
244    WRITE (T,223) ST,ISD,DIP,IDPD
245 223  FORMAT (4H  N,F3.0,1X,A1,F7.0,1X,A3)
246 222  FORMAT (5X,      F3.0,1X,A1,F7.0,1X,A1)
247    ROEC(I)=DIP*0.01745332
248    IF(IDPD.EQ.ID26) GO TO 5059
249    IF(IDPD.EQ.ID31) GO TO 5060
250    IF (ISD.EQ.ID35.AND.IDPD.EQ.ID35) GO TO 5054
251    IF (IDPD.EQ.ID35.AND.ISD.EQ.ID17) GO TO 5055
252    IF (ISD.EQ.ID17.AND.IDPD.EQ.ID17) GO TO 5056
253    GO TO 5057
254 5054 AZ=90.0-ST
255    GO TO 5058
256 5055 AZ=90.0+ST
257    GO TO 5058
258 5056 AZ=270.0+ST
259    GO TO 5058
260 5059 AZ=180.0
261    GO TO 5058
262 5060 AZ=360.0
263    GO TO 5058
264 5057 AZ=270.0-ST
265 5058 AZC(I)=AZ*0.01745332
266 221  CONTINUE
267    RETURN
268    END
269    SUBROUTINE AZMUTH (ID17,ID26,ID31,ID35)
270C    LISTING OF THE PLANES CONVERSION SUBROUTINE
271C    ROUTINES FOR PLANES DATA USING 0-360 DEGREE DATA INPUT
272    INTEGER ID17,ID26,ID31,ID35
273    INTEGER T,S
274    DIMENSION AZC(1250), ROEC(1250)
275    COMMON AZC,ROEC,T,S,N
276    T=23
277    S=22
278    WRITE (T,001)
279 001  FORMAT (5X,15HDATA ARE PLANES/' ',3X,6HSTRIKE,7X,3HDIP///)
280    DO 10 I=1,N
281    READ (S,002) ST,DIP,IDPD
282    WRITE (T,002) ST,DIP,IDPD
283 002  FORMAT(5X,F4.0,F7.0,1X,A1)
284    ROEC(I)=DIP*0.01745332
285    IF(IDPD.EQ.ID26) GO TO 17
286    IF(IDPD.EQ.ID31) GO TO 16
287    IF(IDPD.EQ.ID17) GO TO 20
288    GO TO 30
289    20 IF(ST-90.) 18,28,28
290    28 IF(ST-180.) 3,4,4

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291      4 IF(ST-270.) 3,6,6
292      6 IF(ST-360.) 7,10,10
293      30 IF(IDPD.EQ.ID35) GO TO 40
294      GO TO 10
295      40 IF(ST-90.) 9,11,11
296      11 IF (ST-180.) 12,13,13
297      13 IF(ST-270.) 12,14,14
298      14 IF(ST-360.) 15,10,10
299      18 ST=(360.+ST)-90.
300      GO TO 8
301      3 ST=ST+90.
302      GO TO 8
303      7 ST=ST-90.
304      GO TO 8
305      9 ST=ST+90.
306      GO TO 8
307      12 ST=ST-90.
308      GO TO 8
309      15 ST=(ST+90.)-360.
310      GO TO 8
311      16 ST=180.
312      GO TO 8
313      17 ST=0.
314      8 AZC(I)=ST*0.01745332
315      10 CONTINUE
316      RETURN
317      END
318      SUBROUTINE USTAG (IND,ID1)
319C      LISTING OF THE U-STAGE CONVERSIONS SUBROUTINE
320C      ROUTINES FOR U-STAGE DATA
321      REAL ID1
322      INTEGER T,S
323      DIMENSION AZC(1250),ROEC(1250)
324      COMMON AZC,ROEC,T,S,N
325      T=23
326      S=22
327      IF (IND-4) 250,252,253
328      252 WRITE (T,241)
329      241 FORMAT(' ',5X,'DATA ARE U-STAGE',///,5X,'LINEAR ELEMENTS
330%      NORMAL TO SCOPE AXIS',/,1H1,5X,'AZIMUTH',4X,'INCLINATION',///)
331      GO TO 255
332      253 IF (IND-5) 250,254,255
333      254 WRITE (T,240)
334      240 FORMAT (5X,'DATA ARE U-STAGE',///5X,'LINEAR ELEMENTS PARALLEL TO
335%      SCOPE AXIS',/1H1,5X,'AZIMUTH',4X,'INCLINATION',///)
336      250 CONTINUE
337      255 DO 243 I=1,N
338      READ (S,246) ST,DIP,IDPD
339      246 FORMAT(F5.0,1X,F5.0,A1)
340      WRITE (T,242) ST,DIP,IDPD
341      242 FORMAT(F5.0,1X,F5.0,1X,A1)
342      IF (ST-180.0) 261,261,260
343      260 ST=ST-180.0
344      261 AZ=ST+90.0
345      IF (IDPD-ID1) 263,262,263
346      262 AZ=ST-90.0
347      263 IF (ST-90.0) 245,266,266
348      266 AZ=ST-90.0

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349      IF (IDPD-ID1) 245,267,245
350 267 AZ=ST+90.0
351 245 RO=90.0-DIP
352      IF (IND-4) 268,244,268
353 268 RO=DIP
354      AZ=AZ+180.0
355 244 IF (AZ-0.0) 269,210,210
356 269 AZ=360.0+AZ
357 210 IF (AZ-360.0) 212,212,211
358 211 AZ=AZ-360.0
359 212 ROEC(I)=RO*0.01745332
360      AZC(I)= AZ*0.01745332
361 243 CONTINUE
362      RETURN
363      END
364      SUBROUTINE ROTE (IND,ID17,ID35)
365C      LISTING OF THE ROTATIONS SUBROUTINE
366C      ROUTINE TO ROTATE DATA CONTAINS TWO PARTS
367      INTEGER ID17,ID26,ID31,ID35
368      INTEGER T,S
369      DIMENSION AZC(1250),ROEC(1250),XV(1250),YV(1250),ZV(1250)
370      COMMON AZC,ROEC,T,S,N
371      T=23
372      S=22
373      IR=5
374C      PART ONE READ DATA AS DIP AND STRIKE OF ORIGINAL AND NEW PLANES OF
375C          DATA
376C      CALCULATE ROTATION AS GAMMA AND ALPHA
377      IF (IND-6) 451,450,451
378 450 READ (S,402) IPP,AST1,IAST1,PD1,IPD1,AST2,IAST2, PD2,IPD2
379 402 FORMAT (I1,1X,2(F3.0,1X,A1,F6.0,1X,A1,7X))
380 451 IF (IND-7) 453,452,453
381 452 READ (S,403) IPP,GAMMA,ALPHA
382 403 FORMAT (I1,2F9.2)
383C      IPP = 0 IF AZC AND ROEC ARE TO BE USED AGAIN IN THIS RUN
384C      IPP = 1 IF AZC AND ROEC ARE NOT NEEDED AGAIN
385C      IPP = 3 IF AZC AND ROEC ARE TO BE PUNCHED
386 453 IF (IPP-1) 308,309,310
387 308 IP=IR
388      WRITE (T,305)
389 305 FORMAT (5X,27HROTATION OF EXISTING POINTS///5X,
390& 27HDATA ON TAPE TO BE RETREVED///)
391      GO TO 311
392 309 CONTINUE
393      WRITE (T,307)
394 307 FORMAT (5X,'ROTATION OF EXISTING POINTS',///5X,'DATA WILL BE
395& DISCARDED',///)
396      GO TO 311
397 310 CONTINUE
398      WRITE (T,306)
399 306 FORMAT (5X,'ROTATION OF EXISTING POINTS',///5X,'DATA WILL BE
400& PUNCHED',///)
401 311 IF (IND-7) 454,404,454
402 454      WRITE (T,4021) AST1,IAST1,PD1,IPD1,AST2,IAST2,PD2,IPD2
403 4021 FORMAT (1H0/5X,37HDIP AND STRIKE OF ORIGINAL DATA PLANE//10X,1HN,
404& F4.0,A1,F7.0,A1///5X,39HDIP AND STRIKE OF ROTATED TO DATA PLANE//
405& 10X,1HN,F4.0,A1,F7.0,A1///)
406C      AZ(1 AND 2) =0.0 TO EAST

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407      AZ1=180.0+AST1
408      AZ2=180.0+AST2
409      IF (IAST1-ID17) 982,981,982
410 981 AZ1=360.0-AST1
411 982 IF (IAST2-ID17) 984,983,984
412 983 AZ2=360.0-AST2
413 984 IF (IAST1-ID17) 987,985,987
414 985 IF (IPD1-ID17) 987,986,987
415 986 AZ1=180.0-AST1
416 987 IF (IAST2-ID17) 972,970,972
417 970 IF (IPD2-ID17) 972,971,972
418 971 AZ2=180.0-AST2
419 972 IF (IAST1-ID35) 975,973,975
420 973 IF (IPD1-ID35) 975,974,975
421 974 AZ1=AST1
422 975 IF (IAST2-ID35) 978,976,978
423 976 IF (IPD2-ID35) 978,224,978
424 224 AZ2=AST2
425 978 VERT2=PD2*0.01745332.
426      VERT1=PD1*0.01745332
427      AZ2=(AZ2-AZ1)*0.01745332
428      ALPHA=VERT1
429      XYC=SIN(VERT2)
430      ZXC=COS(VERT2)
431      XXC=XYC*COS(AZ2)
432      YYC=XYC*SIN(AZ2)
433      IF (ABS(YYC)-0.99) 1020,1020,4025
434 1020 XZC=SQRT(XXC*XXC+ZXC*ZXC)
435      QR=ZXC/XXC
436      ROT=ATAN(QR)+ALPHA
437      IF (ROT-3.14159) 941,941,940
438 940 ROT=ROT-3.14159
439 941 IF (ROT-0.0) 942,943,943
440 942 ROT=ROT+3.14159
441 943 ZXC=SIN(ROT)*XZC
442      XXC=XZC*COS(ROT)
443      XYC=SQRT(XXC*XXC+YYC*YYC)
444      IF (ZXC-0.99) 4025,4025,4026
445 4025 QR=YYC/XXC
446      AZ2=ATAN(QR)+AZ1*0.01745332
447      GO TO 4027
448 4026 AZ2=0.0
449 4027 QR=XYC/ZXC
450      VERT2=ATAN(QR)
451      GAMMA=AZ2*57.2957
452      ALPHA=VERT2*57.2957
453 404 IF (GAMMA-0.01) 916,918,918
454 916 IF (ALPHA-0.01) 320,918,918
455 918 ALPHR=ALPHA*0.01745332
456      GAMR =GAMMA*0.01745332
457      WRITE (T,4022) GAMMA,ALPHA
458 4022 FORMAT (10H0 GAMMA =,F10.2///9H ALPHA =,F10.2///)
459C      PART TWO      ROTATING THE DATA
460      DO 300 I=1,N
461      AZ=AZC(I)+GAMR
462      XY=SIN(ROEC(I))
463      ZZ=COS(ROEC(I))
464      XX=XY*SIN(AZ)

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465      YV(I)=XY*COS(AZ)
466      IF (ABS(YV(I))-0.99) 1001,1001,301
467 1001  XZ=SQRT(XX*XX+ZZ*ZZ)
468      QR=ZZ/XX
469      AROT=ATAN(QR)+ALPHR
470      IF (AROT-3.14159) 1003,1003,1002
471 1002  AROT=AROT-3.14159
472 1003  IF (AROT-0.0) 1004,1005,1005
473 1004  AROT=AROT+3.14159
474 1005  ZV(I)=XZ*SIN(AROT)
475      XV(I)=XZ*COS(AROT)
476      XY=SQRT(XV(I)*XV(I)+YV(I)*YV(I))
477      IF (ZV(I)-0.99) 301,301,302
478 301   QR=XV(I)/YV(I)
479      AZC(I)=ATAN(QR)-GAMR
480      QR=XY/ZV(I)
481      ROEC(I)=ATAN(QR)
482      GO TO 303
483 302  AZC(I)=0.0
484      ROEC(I)=0.0
485 303  WRITE (24,304) AZC(I),ROEC(I)
486 304  FORMAT (2F10.6)
487 300  CONTINUE
488 320  CONTINUE
489      RETURN
490      END
491      SUBROUTINE PRT1 (DUMMY)
492C      LISTING OF THE SYMBOL TABLE PRINT SUBROUTINE
493C      ROUTINE TO PRINT SYMBOL TABLE
494      INTEGER T,S
495      DIMENSION AZC(1250),ROEC(1250),DUMMY(40)
496      COMMON AZC,ROEC,T,S,N
497      T=23
498      S=22
499      WRITE (T,550) (DUMMY(I),I=1,3)
500 550  FORMAT (1H1,'SYMBOLS ON STERO-NET MEAN',////5X,'SYMBOL', 7X,
501 550  'PERCENT RANGE',//8X,A1,9X,'0 OR LESS',/8X,A1,9X,'0',3X,'1/2'/8X,
502 550  A1,8X,'1/2',4X,1H1)
503      I=I+1
504      DO 551 I=4,37
505      MBO=I-3
506      MTO=I-2
507 551  WRITE (T,552) DUMMY(I),MBO,MTO
508 552  FORMAT (8X,A1,8X,I2,4X,I2)
509      WRITE (T,553) DUMMY(38)
510 553  FORMAT (8X,A1,8X,14H35 AND GREATER////////)
511      RETURN
512      END

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*

Beta (β) intersection diagrams are plots of the line(s) of intersection of two or more planes on an equal area net. The number of intersections possible is given by the formula: $(n \times (n-1))/2$, where n is the number of planes (e.g. if $n=30$, $30 \times 29 / 2 = 435$ points). These diagrams are very time consuming to produce by hand.

The program BETACAL is a FORTRAN program that reduces field data (azimuthal strike and dip) to vector solutions of the intersections for a given plane with all other planes in the data set. This is done in such a way as to eliminate duplication of points. The output from this program is in a form compatible with the PIPLOT plotting and contouring routine, which is used to produce the final diagram.

Input on title and control card:

<u>COLUMN</u>	<u>INPUT</u>	<u>EXPLANATION</u>
1-2	number of data sets	(from 2-50)
8-80	title for identification of data	

Input on data cards:

5-8	strike	(e.g. 340.)
15-19	dip and dip direction	(NN, SS, EE, WW, NE, NW, SE, SW)

An end of data card, a zero in columns one and two, must be the last card in the data deck.

The maximum number of planes that can be used in a single data set is fifty. However, several data sets can be stacked for a single run. The output from BETACAL is

in two forms; a printed listing of the intersections and a file containing the intersections in quadrant form for use with the PIPLOT plotting and contouring routine.

BETACAL was developed by the author and G.T. Benson for use with a Honeywell 66/20 computer.

PROGRAM LISTING

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01C  PROGRAM BETA.  BETA INTERSECTION CALCULATION PROGRAM
02    DIMENSION KD(50),AZ(50),DIP(50),TITLE(72),APX(50),APY(50),
03    A(50),B(50),X(1250),Y(1250),BRG(1250),PLG(1250),AZC(50),
04    AZQ(50),DIPC(50)
05    DATA ID1,ID2,ID3,ID4,ID5,ID6,ID7,ID8/'NN','SS','EE','WW',
06    'NE','NW','SE','SW'/
07    DATA M1,M2,M3,M4/'N','S','E','W'/
08    Z=100.
09 555 READ(22,100) N,(TITLE(I),I=1,72)
10    IF(N.EQ.00) GO TO 999
11    WRITE(6,200) (TITLE(I),I=1,72),N
12    WRITE(23,333) N,(TITLE(I),I=1,72)
13 333 FORMAT(I2,10X,72A1)
14    WRITE(6,201)
15    DO 10 I=1,N
16    READ(22,101) AZ(I),DIP(I),KD(I)
17    WRITE(6,202) AZ(I),DIP(I),KD(I)
18 10 CONTINUE
19    DO 11 I=1,N
20    IF(AZ(I)-270.) 7,8,7
21 8 AZQ(I)=(-270.)
22    GO TO 14
23 7 IF(AZ(I)-90.) 12,13,13
24 12 AZQ(I)=AZ(I)
25    GO TO 14
26 13 AZQ(I)=(-360.)+AZ(I)
27    GO TO 14
28 14 AZC(I)=AZQ(I)*0.01745332
29    DIPC(I)=DIP(I)*0.01745332
30    APX(I)=TAN(DIPC(I))*SIN(AZC(I))
31    IF(APX(I)+0.) 1,2,1
32 2 A(I)=1.0E03
33    GO TO 3
34 1 A(I)=Z/APX(I)
35 3 APY(I)=TAN(DIPC(I))*COS(AZC(I))
36    IF(APY(I)+0.) 4,5,4
37 5 B(I)=1.0E03
38    GO TO 6
39 4 B(I)=Z/APY(I)
40 6 IF(KD(I).EQ.ID5) GO TO 15
41    IF(KD(I).EQ.ID7) GO TO 15
42    IF(KD(I).EQ.ID8) GO TO 17
43    IF(KD(I).EQ.ID6) GO TO 17
44    IF(KD(I).EQ.ID2) GO TO 15
45    IF(KD(I).EQ.ID3) GO TO 15
46    IF(KD(I).EQ.ID4) GO TO 17
47    GO TO 11
48 15 A(I)=A(I)*(-1.)
49    GO TO 11
50 17 B(I)=B(I)*(-1.)
51 11 CONTINUE
52    WRITE(6,203)
53    L=0
54    DO 18 I=1,N
55    M=I+1
56    IF(M.GT.N) GO TO 18
57    DO 19 J=M,N
58    L=L+1

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59     IF(DIP(I)-90.) 99,98,97
60 97 WRITE(6,208) I
61     GO TO 999
62 98 IF(DIP(J)-90.) 96,95,94
63 94 WRITE(6,208) J
64     GO TO 999
65 95 BRG(L)=999.
66     PLG(L)=90.
67     GO TO 850
68 96 BRG(L)=AZ(I)
69     IF(KD(J).EQ.ID7) GO TO 93
70     IF(KD(J).EQ.ID8) GO TO 93
71     IF(KD(J).EQ.ID2) GO TO 93
72     IF(KD(J).EQ.ID4) GO TO 700
73     GO TO 92
74 93 IF(AZ(I)-90.) 600,600,601
75 600 BRG(L)=180.+AZ(I)
76     GO TO 92
77 601 BRG(L)=180.-AZ(I)
78     GO TO 92
79 700 IF(AZ(I)-90.) 701,701,702
80 701 BRG(L)=180.+AZ(I)
81     GO TO 92
82 702 BRG(L)=AZ(I)
83 92 PHI=ABS((AZ(I)-AZ(J))*0.01745332)
84     PLG(L)=ABS(ATAN(TAN(DIPC(J))*SIN(PHI)))
85     PLG(L)=PLG(L)*0.01745332
86     PLG(L)=PLG(L)+0.5
87     GO TO 850
88 99 IF(DIP(J)-90.) 40,41,42
89 42 WRITE(6,208) J
90     GO TO 999
91 41 BRG(L)=AZ(J)
92     IF(KD(I).EQ.ID8) GO TO 43
93     IF(KD(I).EQ.ID7) GO TO 43
94     IF(KD(I).EQ.ID2) GO TO 43
95     IF(KD(I).EQ.ID4) GO TO 802
96     GO TO 44
97 43 IF(AZ(J)-90.) 800,800,801
98 800 BRG(L)=180.+AZ(J)
99     GO TO 44
100 801 BRG(L)=180.-AZ(J)
101     GO TO 44
102 802 IF(AZ(J)-90.) 803,803,804
103 803 BRG(L)=180.+AZ(J)
104     GO TO 44
105 804 BRG(L)=AZ(J)
106 44 PHI=ABS((AZ(I)-AZ(J))*0.01745332)
107     PLG(L)=ABS(ATAN(TAN(DIPC(I))*SIN(PHI)))
108     PLG(L)=PLG(L)/0.01745332
109     PLG(L)=PLG(L)+0.5
110     GO TO 850
111 40 Y(L)=(A(I)-A(J))/((A(I)/B(I))-(A(J)/B(J)))
112     X(L)=A(I)-(Y(L)*(A(I)/B(I)))
113     BRG(L)=ATAN(Y(L)/X(L))
114     BRG(L)=BRG(L)/0.01745332
115     IF(KD(I).EQ.ID6.AND.KD(J).EQ.ID6) GO TO 5555
116     IF(KD(I).EQ.ID6.AND.KD(J).EQ.ID8) GO TO 5555

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117      IF(KD(I).EQ.ID8.AND.KD(J).EQ.ID6) GO TO 5555
118      IF(KD(I).EQ.ID8.AND.KD(J).EQ.ID8) GO TO 5555
119      IF(X(L)-0.) 24,25,25
120 24 IF(Y(L)-0.) 27,26,26
121 25 IF(Y(L)-0.) 28,29,29
122 5555 IF(X(L)-0.) 5551,25,25
123 5551 IF(Y(L)-0.) 26,27,26
124 26 BRG(L)=BRG(L)+180.
125      GO TO 29
126 27 BRG(L)=270.-BRG(L)
127      GO TO 29
128 28 BRG(L)=BRG(L)+360.
129 29 PLG(L)=ABS(ATAN(Z/SQRT((X(L)**2)+(Y(L)**2))))
130      PLG(L)=PLG(L)/0.01745332
131      PLG(L)=PLG(L)+0.5
132      BRG(L)=BRG(L)+0.5
133      IF(AZ(I)-AZ(J)) 53,52,53
134 52 BRG(L)=AZ(I)
135      PLG(L)=0.0
136      IF(BRG(L)+0.)55,850,850
137 55 BRG(L)=BRG(L)+360.
138      GO TO 850
139 53 ZX=ABS(AZ(I)-AZ(J))
140      IF(ZX-180.) 850,52,850
141 850 IF(KD(I).EQ.ID8.AND.KD(J).EQ.ID2) GO TO 851
142      IF(KD(I).EQ.ID2.AND.KD(J).EQ.ID8) GO TO 851
143      IF(KD(I).EQ.ID6.AND.KD(J).EQ.ID2) GO TO 852
144      IF(KD(I).EQ.ID2.AND.KD(J).EQ.ID6) GO TO 852
145      GO TO 853
146 851 BRG(L)=BRG(L)-45.
147      GO TO 853
148 852 BRG(L)=BRG(L)+45.
149 853 WRITE(6,204) I,J,BRG(L),PLG(L)
150      IF(BRG(L)-90.) 6000,6000,6001
151 6000 BRG(L)=BRG(L)
152      KP1=M1
153      KP2=M3
154      GO TO 6008
155 6001 IF(BRG(L)-180.) 6002,6002,6003
156 6002 BRG(L)=180.-BRG(L)
157      KP1=M2
158      KP2=M3
159      GO TO 6008
160 6003 IF(BRG(L)-270.) 6004,6004,6005
161 6004 BRG(L)=BRG(L)-180.
162      KP1=M2
163      KP2=M4
164      GO TO 6008
165 6005 IF(BRG(L)-360.) 6006,6007,6007
166 6006 BRG(L)=360.-BRG(L)
167      KP1=M1
168      KP2=M4
169      GO TO 6008
170 6007 BRG(L)=0.
171      KP1=M1
172      KP2=M4
173 6008 WRITE(23,9876) KP1,BRG(L),KP2,PLG(L)
174 9876 FORMAT(3X,A1,F3.0,1X,A1,F8.0)

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175 19 CONTINUE
176 18 CONTINUE
177 WRITE(6,9877) L
178 9877 FORMAT(/,/,/,5X,'THE NUMBER OF INTERSECTIONS IS ',I5,/,/,/,/,/)
179 GO TO 555
180 100 FORMAT(I2,5X,72A1)
181 101 FORMAT(4X,F4.0,6X,F3.0,1X,A2)
182 200 FORMAT(5X,72A1,/,/,/,5X,I2,' DATA SETS')
183 201 FORMAT(10X,'STRIKE',3X,'DIP',5X,'DIP QUAD.')
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184 202 FORMAT(11X,F4.0,4X,F4.0,9X,A2)

185 203 FORMAT(2X,'ISECT',2X,'BEARING',3X,'PLUNGE')

186 204 FORMAT(2X,I2,'-',I2,3X,F4.0,7X,F3.0)

187 208 FORMAT(10X,'INPUT ERROR AT DATA LINE ',1X,I2,2X,'PROG. ABORT')

188 999 STOP

189 END

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APPENDIX B

AREAL EXTENT OF AERIAL PHOTO MAPPING

Due to inaccessability, a portion of the study area was mapped solely on the basis of aerial photo interpretation. The extent of this mapping is shown by the shaded area in Figure 34.