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BEDROCK GEOLOGY OF U.S. COAST GUARD RESERVATION, KODIAK, ALASKA

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INTRODUCTION

Bedrock geological studies in the area of the U.S. Coast Guard Reservation, Kodiak, Alaska were undertaken in August 1988. This study is part of an Alaska Division of Geological and Geophysical Surveys (ADGGS) project to provide detailed information on bedrock and unconsolidated deposits in the study area (Figure 1), at the request of the U.S. Geological Survey Water Resources Division, Anchorage. Also included in the ADGGS project are reports and maps on surficial geology (by R.A. Combellick; PDF 89-8B), shallow seismic-refraction profiling (by R.D. Allely; PDF 89-8C), and bedrock geotechnical properties (by J.M. Brown; 89-8D).

The goals of the bedrock study were to 1) map the areal distribution of types of bedrock and joint orientations, and 2) to describe the characteristics of bedrock. Plates 1 - 3 are maps of bedrock structure data for each of the three map areas (Figure 1). Outcrop distribution is also shown on the geologic maps (Plates 4, 5 and 6) in PDF 89-8B. Appendix 1 is a compilation of all measured bedrock structural data, and the following report discusses the geology, rock types, and structure of bedrock in the study area.

PREVIOUS STUDIES

The earliest geologic map of Kodiak Island was compiled in 1912 by G.C. Martin on the basis of his own and others' field observations. At that time, it was recognized that slates and graywackes composed the major portion of the island, and these rocks were tentatively assigned a Mesozoic age (Martin, 1913). The other lithologic units which occur on Kodiak Island were also recognized, though the areal extent of each unit, particularly of the intrusives, was not determined.

S.R.Capps spent two field seasons (1934 and 1935) on Kodiak Island, and the comprehensive results of his investigations are presented in USGS Bulletins 868-B (1937a) and 880-C (1937b). His lithologic descriptions based on field observations are thorough and accurate. Other early geologic work on Kodiak relates primarily to placer and lode gold deposits, and these topical reports do not focus on the area of our study.

Geologic mapping by G.W.Moore during the summers of 1962, 1963 and 1965 led to publication of a preliminary geologic map of Kodiak Island and vicinity (Moore, 1967). On his map, Moore assigned all of the rocks within our study area to the Cretaceous unit of "marine sedimentary rocks". This unit was formally named the Kodiak Formation in 1969 (Moore, 1969). The type section is along the west shore of Uyak Bay, which is on the opposite side of the island, about 85 km southwest of our study area. A report summarizing previously known geology and mineral deposits of Kodiak Island (McGee, 1972) shows a mineral claim (commodity unreported) along the coast just northeast of our study area. Other mineral claims, northwest of Erskine Mountain and outside our study area, suggest enrichment in tungsten and gold (McGee, 1972).

Subsequent study of the Kodiak Formation focused on stratigraphy and interpretation of depositional environment. The formation is interpreted as a turbidite deposit of basin-plain and slope facies, with southwestward paleocurrent transport (Nilsen and Bouma, 1977; Nilsen and Moore, 1979; Nilsen, 1983/1984).

Most recent geologic investigations of the Kodiak Formation relate primarily to its structure and tectonic setting. These studies, undertaken principally by researchers from the University of California at Santa Cruz, suggest that the Kodiak Formation has undergone a series of deformational events as a result of continued underplating, crustal tilting and folding, thrusting, and strike-slip faulting within an accretionary wedge (Sample, 1984; Sample, 1985; Sample and Moore, 1987; Fisher, 1984; Fisher, 1985; Sample and Fisher, 1986).

GEOLOGIC SETTING

Our entire study area (Figure 1) is underlain by a part of the Cretaceous Kodiak Formation. This formation is thought to be approximately 5,000 m thick, with much structural repetition due to folds and faults (Nilsen and Moore, 1979). The Kodiak Formation rocks were deposited as part of a turbidite sequence (Nilsen and Moore, 1979), containing basin-plain and slope facies associations, as defined by Mutti and Ricci Lucchi (1978). The turbidity currents are thought to have flowed southwestward during deposition of the Kodiak Formation (Nilsen and Moore, 1979).

The Kodiak Formation is part of a 1,700 km-long belt of Cretaceous turbidite flysch and melange along the Gulf of Alaska margin (Plafker and others, 1977). This belt, which is called the Chugach terrane, is bounded on the north by the Border Ranges Fault and to the south by the Contact Fault in southcentral Alaska (Plafker and others, 1977).

As a result of interplate tectonism, the turbidites of the Chugach terrane were accreted against older adjacent rocks of the Peninsular terrane, causing complex deformation of the turbidites (Sample and Moore, 1987). Accretion is thought to have been complete by early Paleocene, based on undisturbed Paleocene intrusive dikes across the terrane boundary (Davies and Moore, 1984).

METHODS OF INVESTIGATION

Field bedrock investigations were undertaken from August 15 through 27, 1988 by Alaska Division of Geological and Geophysical Surveys (ADGGS) geologists. Outcrops of the project area were studied to determine rock type, structural orientation and a variety of lithologic details. Two days of helicopter field work facilitated access to outcrops in the more remote parts of the project area. Bedrock structural data such as bedding and foliation planes, fold axes, quartz veins, and fracture planes were collected using hand-held Brunton compasses. These data are shown on Plates 1, 2, and 3. Since the entire project area is underlain by a single geologic unit (Kodiak Formation), no geologic contacts were mapped. Mapping of individual lithologic layers proved to be unfeasible due to thinness of beds and limited extent of exposure. Petrographic analysis of 10 thin sections yielded details of mineralogy and structure to assist in rock descriptions. Structural orientation data was plotted using the Macintosh program 'Stereonet (version 2.6)' by R.W.Allmendinger (Figures 2 - 12).

ROCK DESCRIPTIONS

Kodiak Formation rocks within our study area consist of dark-gray to black mudstone, siltstone, sandstone and conglomerate which have undergone varying degrees of compaction and low-grade metamorphism. Fine-grained rocks range from shale to slate, with a phyllitic sheen locally. The ratio of sandstone to shale/slate ranges from 10:1 to 1:1, with very fine- to fine-grained (1/16 to 1/4 mm) sandstone the most abundant. Sandstone and shale layers are laterally continuous at outcrop scale without changes in thickness or grain size. Bedding is generally thin (1 - 4 cm), and parallel-bedded. In areas of good preservation, particularly in coastal exposures, depositional features can be observed, such as graded bedding, erosive bases of beds, lode casts, and ripple marks. Paleocurrent indicators, predominantly lode-casts, suggest west and southwest flow directions. Tops of beds, where observable, face toward the northwest.

The sedimentologic analyses of turbidite deposits may be condensed here for the sake of brevity into a three-fold description: 1) Individual bed subdivisions (Bouma Divisions Ta-Te), 2) Turbidite bed Facies (Facies A-G) and, 3) Facies associations and depositional environments. For the Kodiak Formation in our study area these three aspects are summarized below.

1) Individual bed subdivisions (Bouma Divisions): Individual bed subdivisions which represent depositional flow regimes can be described using the Bouma (1962) terminology. For our study area these divisions are predominantly Ta through Te (massive and graded coarse-grained sand grading upward to mud), and Tc through Te (convolute-laminated sand and silt grading upward to mud).

2) Turbidite bed Facies (Facies A-G): Each turbidity current deposit can be described in terms of one of Mutti and Ricci Lucchi's (1978) Facies A through G, where each Facies represents one or more depositional processes. Kodiak study area turbidites are predominantly Facies C and D.

3) Facies associations and depositional environments: Facies associations can be interpreted in terms of depositional environments. Facies C and D turbidites represent an outer fan depositional environment.

The Facies C and D deposits have plane-parallel graded bedding, localized channelization, extensive lateral continuity (>30 m, or length of largest outcrop observed) of interbedded sandstone and shale. Thickening- and coarsening-upward cycles on Nyman Peninsula, between Finny Beach (north) and Peninsula Lake (south) repeat over intervals of approximately 3 per 100 m of section. Channelization occurs in the upper thick sandstone beds, where local channels prograded over, and eroded into, the sheet-like lobe deposits. Channels may have erosive bases, are typically amalgamated (to 1 m thick) and consist of medium-grained sandstone. Locally, channels occur as highly erosive deposits and may have abundant shale rip-ups (to tens of cm along long axis).

Quartz veins both crosscut and parallel cleavage and bedding, ranging in thickness from much less than 1 mm to several cm. These veins, though in places vuggy, in general do not contain continuous open spaces, unless broken by late brittle fracturing. Calcite veins are also present, but are thinner and less abundant than quartz veins. On the whole, there appear to be fewer quartz veins in the western part of the study area.

SHALES / SLATES: The layers of mud- and silt-size grains are typically thin to laminated, and dark gray to black. Mineralogy includes 30-70% quartz, 2-15% opaque material, 1-30% plagioclase, 1-15% carbonate, <1-5% white mica, with minor biotite and pyrite in some samples. Weathering effects are slight to moderate; rock hardness ranges from soft to moderately hard, depending on induration of the rock and intensity of weathering. In a broad sense, the degree of induration is greater in the western portion of the study area, with slate more common there than shale. Pressure cleavage is extremely closely spaced, typically irregular and wavy, filled with insoluble opaque material, and in some cases has very fine-grained secondary micaceous mineral growth which yields a phyllitic sheen. This cleavage is parallel to bedding, to slightly oblique to bedding. In rare cases, clasts (< 1 cm) of sandstone and shale are included within slate layers. Pressure shadows at the margins of some larger grains are symmetrical, and there is no indication of ductile shear movement. The intense compaction and secondary mineral growth in these rocks results in low porosity. However, subsequent fracturing (discussed below) may locally result in increased permeability.

SANDSTONES: Sandstone layers are typically 1 to 8 cm thick, parallel bedded, graded, with locally erosive bases. Grain size is predominantly fine- to very fine, with minor (roughly 20 percent) medium-grained sandstone. Most contain > 15% matrix material and abundant plagioclase and lithic fragments, and thus may be classified as feldspathic lithic graywackes (Pettijohn and others, 1972). The rocks are dark gray to black. They are generally fresh, and hard to very hard, though in smaller, more weathered outcrops, sandstones may be moderately weathered and only moderately hard. Pyrite grains up to 3 mm in diameter are randomly distributed, forming < 1 percent of the rock. Sand-sized grains include quartz and plagioclase in all samples, and minor white mica, biotite, chlorite, epidote(?), and opaque minerals in some samples. Carbonate is intergranular, and replaces plagioclase in some samples. Fine-grained lithic fragments include microcrystalline chert, black shale, and fragments of volcanogenic plagioclase microlites and chlorite. Grains are subangular to subrounded, and generally poorly sorted. Egg-sized iron concretionary nodules are locally distributed in some thicker sandstone layers.

Pressure solution cleavage is typically extremely closely to closely spaced (< 1 mm to 3 cm), and parallel or slightly oblique to bedding. There is no shear sense indicated in thin section. Pressure shadows fringe larger grains, and indicate phyllosilicate growth during shortening. This pressure solution deformation and mineral growth results in rocks of low porosity prior to fracturing.

CONGLOMERATES: Conglomerates are volumetrically minor (roughly <5 percent of exposure), and form channel deposits. These localized deposits contain abundant shale rip-up clasts which range from 20 cm x 2 cm to 5 mm x 1 mm; all shale clasts are angular and flattened parallel to bedding. Other clasts are microcrystalline chert, volcanogenic grains of plagioclase microlites and chlorite, and quartz pebbles and granules. The clasts are sandstone matrix-supported, with subangular to subrounded sand-sized grains of quartz (some with apatite inclusions), plagioclase and carbonate, with some chlorite, white mica and biotite. Clast-to-matrix ratios are variable, but always less than 1:1.

Pressure solution cleavage tends to be poorly developed in the conglomerates, with opaque residue along the irregular cleavages. There is no strong preferred orientation of matrix grains, and no shear sense. Although in some cases intergranular spaces around larger clasts may lead to greater porosity in conglomerates than in finer-grained rocks, the more irregular pattern of fracture development probably does not lead to significantly greater permeability in the coarser-grained rocks.

LIMESTONES: Limestones are rare and interlayered with shales and sandstones. They are volumetrically minor (<1 - 2 percent of exposure), laminated to medium bedded, very fine-grained, dark to medium gray, and weather light greenish to light-gray or dark-brown. Limestone layers tend to pinch and swell laterally across the outcrop. Weathering effects are light to moderately severe; the fresh rock is hard. Carbonate constitutes at least 50 percent of the rock; the rest is angular to subrounded quartz, opaque minerals (including pyrite), with some plagioclase, and traces of white mica, biotite and chlorite. Pressure solution cleavage is irregularly developed, with wavy, discontinuous stylolites. Shale clasts are locally included in limestone layers, suggesting deposition by turbidity currents. Secondary porosity in these layers is probably low.

TUFFS: Only one tuff layer was found in the study area, in the coastal exposure (station location 88DNS295; Plate 1). This layer pinches and swells, up to 10 cm thick, for several tens of meters laterally. The rock is medium dark green-gray, weathers light green, and has laminated foliations. It is very altered, and mineralogy includes quartz, sericite, chlorite and carbonate.

STRUCTURAL DESCRIPTIONS

BEDDING: Bedding orientation throughout the study area is remarkably consistent, with strike centering around N30E to N40E, and most dips ranging from 75 to 90W. Lower hemisphere equal area stereonet projections of measured poles to bedding plane orientations are shown in Figure 2, 3 and 4. These stereonet diagrams represent 302 measurements from the three map areas (map area I here includes only those areas not included in areas II and III). These plots illustrate the close similarity of bedding orientations in each map area, with perhaps just a slightly more northeasterly strike in map area I (that is, areas in Plate 1 not included on Plates 2 or 3). Also evident is the spread in dips. Though most are steeply to the northwest, there are some anomalously shallow dips, particularly in map areas I and III (Plate 3). All map areas have a minor population of steeply southeast-dipping beds; where tops of beds can be discerned, these are overturned.

Beds range in thickness from laminated to thick (<1 mm to 2 m), with thin-bedded as the most common. Partings between beds are commonly broken, suggesting interbed movement. This is particularly true of the finer-grained, laminated rocks, leading to increased inter-bed permeability in these finer-grained intervals.

CLEAVAGE: Cleavage is typically closely- to extremely closely-spaced (<1 mm to 3 cm), but not crenulated. It is formed by pressure solution, in which in the presence of fluid, material dissolves, predominantly along faces perpendicular to the direction of principal stress, leaving a residue of insoluble material along those faces. This is seen in the Kodiak thin sections as opaque material along cleavages. The dissolved material was redeposited in pressure shadows or may have been transported and redeposited as quartz veins, as suggested by Sample and Moore (1987). Micaceous mineral growth along cleavages is sparse, and seen most commonly in samples from the western part of the study area. Due to subsequent brittle deformation, slip along cleavage planes is common, and may result in increased secondary permeability.

Cleavage orientations roughly parallel those of bedding planes, and in many instances the two are indistinguishable. Where cleavage is oblique to bedding, it is generally steeper than the bedding, and appears to be axial planar to isoclinal folding. Also, the cleavage-steeper-than-bedding suggests an upright position of the fold limbs. Measured orientations of 63 cleavage planes are shown, by map area, on lower hemisphere equal area stereonets (Figures 5, 6 and 7).

FOLDS: Folds (F1 folds of Sample and Moore, 1987) are evident at outcrop scale, and are commonly truncated at their fold noses by fault offset. Folds are generally isoclinal throughout the map area; kink folds were observed, particularly in the eastern portion of the area, but are not common.

Thirteen measurements of fold axis orientations from isoclinal folds are plotted on the lower hemisphere equal area stereonet diagrams in Figure 8. Orientations are widely distributed, but the strongest grouping (6 measurements) is fairly shallow-plunging (approximately 15^{O}) to the southwest and striking approximately parallel to bedding and cleavage. Open folds with axes dipping gently to the northwest were observed along the highway southwest of the entrance to the U.S Coast Guard Base (Plate 3).

FAULTS: Fractures along which there is evidence for displacement were designated as faults. Many fractures may also be faults, but due to the lack of marker beds, displacement commonly cannot be documented. Sample and Moore (1987) outline three episodes of faulting on the southeast side of Kodiak Island: 1) syn-cleavage thrust faults, 2) late thrust faults, and 3) right-lateral strike-slip faults.

Seven measured fault orientations show a broad spread of steeply northwest-dipping planes, whose strikes center around the bedding and cleavage orientation, approximately N35E (Figure 9). Observed faults are commonly repeated at wide intervals in a subparallel fashion across the outcrop. Faults are commonly thin, clean planes of breakage, along cleavage, resulting in hairline-thin planar open spaces. In some cases, however, faults may contain gouge material up to 0.5 m thick, especially in faults which are not parallel to cleavage. Quartz veins are commonly offset by faults; in many cases offset is small, on the order of a few centimeters or less. Sense of movement varies, but typically it is of inland-side-up movement. This is consistent with the southward direction of thrust faulting (Sample and Moore, 1987). Slickensides on fault planes are preserved in some cases, and commonly indicate subhorizontal movement, consistent with the late strike-slip faulting described by Sample and Moore (1987).

FRACTURES: All observed outcrops in the study area contain at least one set of fractures. Most contain two or more, but rarely are more than two sets well-developed. The most common is oriented perpendicular to bedding/cleavage. This fracture system ranges in spacing from extremely close to wide (<1 mm to >1 m), with a general tendency toward closer spacing in finer-grained rocks. Typically the surfaces of all fracture sets are unfilled, with rough, wavy to planar surfaces. In exposed outcrops, the walls of the fractures are commonly separated slightly (< <1 mm to < 1 cm). Thus, fracture-related permeability would tend to be greatest in finer-grained rocks, which are present, in variable percentages, in almost all outcrops.

Figures 10, 11 and 12 are lower hemisphere equal area stereonets representing measurements of 383 fracture orientations throughout the study area. They are separated into map areas I, II and III, with symbols differentiating the more closely spaced sets (extremely close to moderate) from the more widely spaced sets (moderate to wide). The spacings overlap to a great extent, in all map areas, although there is a tendency for the steeply dipping northwest-striking set to be more closely spaced. A population of shallowly dipping fractures, generally less well-developed in outcrop, ranges from close to wide spacing.

SUMMARY

Overall, the bedrock geology of the Kodiak U.S. Coast Guard Reservation study area is remarkably homogeneous in terms of both rock type and structure. Outcrops typically consist of thin- to medium-bedded, dark gray to black siltstone and sandstone, with local mudstone and conglomerate. Limestone and tuff layers are present, but minor. All of the rocks have been subjected to compaction and varying degrees of low-grade metamorphism. Bedding is generally steeply dipping, with a typical strike of about N35E. Cleavage commonly parallels or is closely oblique to bedding. Isoclinal folding and small scale faulting appear to be prevalent, though not readily measured due to the lack of distinct marker beds. There is a prominent fracture system oriented approximately perpendicular to bedding, and a tendency for finer-grained rocks to be more thinly bedded and more closely fractured. Additional fracture sets are less well-developed, and vary between outcrops.

ACKNOWLEDGMENTS

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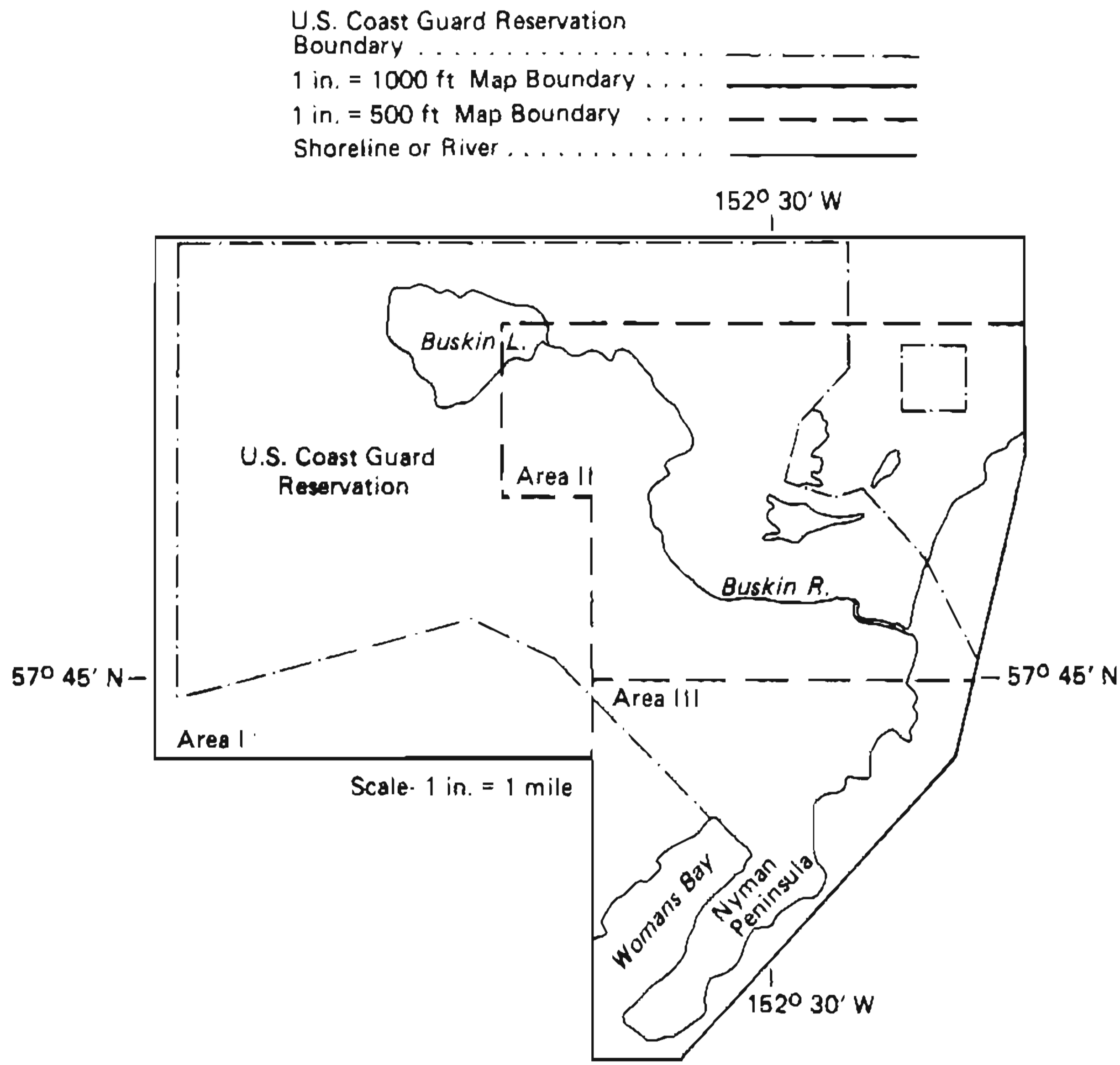

Figure 1. Location map of study area and index of areas shown on plates. Area I includes Areas II and III.

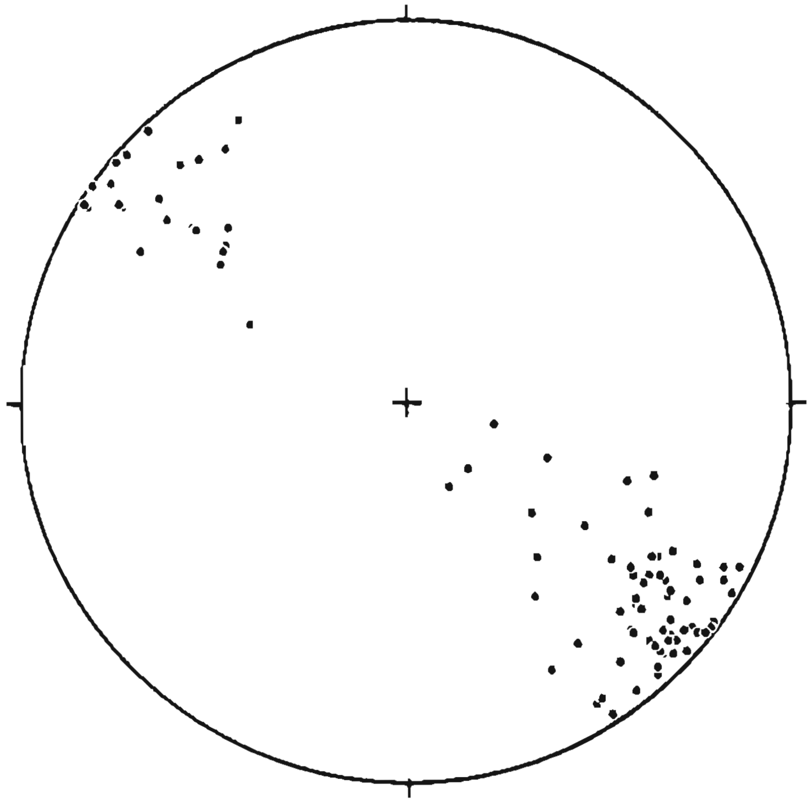

Figure 2. Poles to bedding planes, map area I (excluding areas II and III)

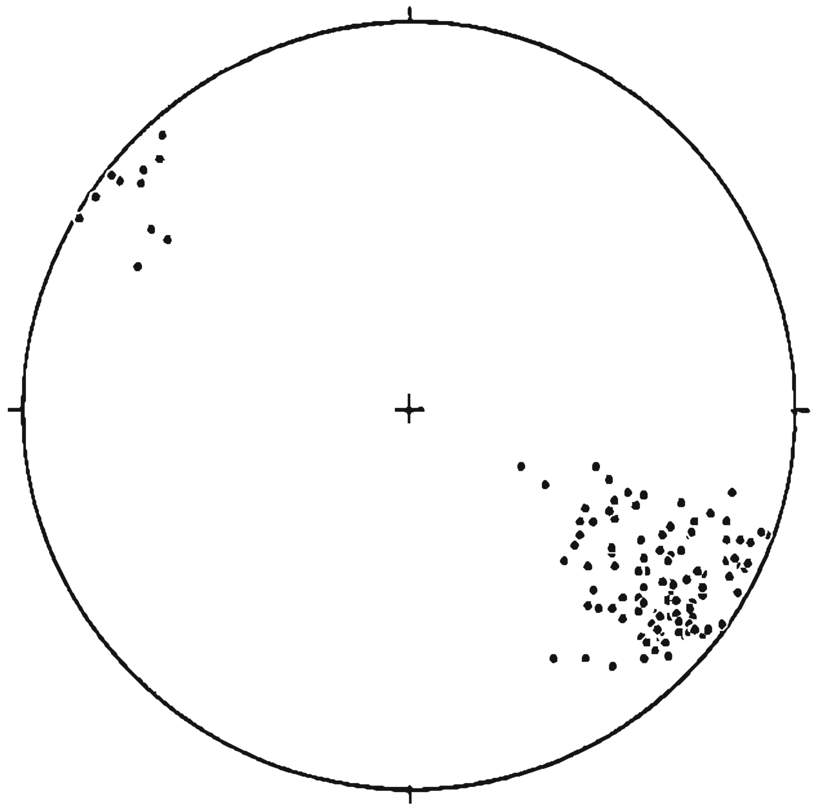

Figure 3. Poles to bedding planes, map area II

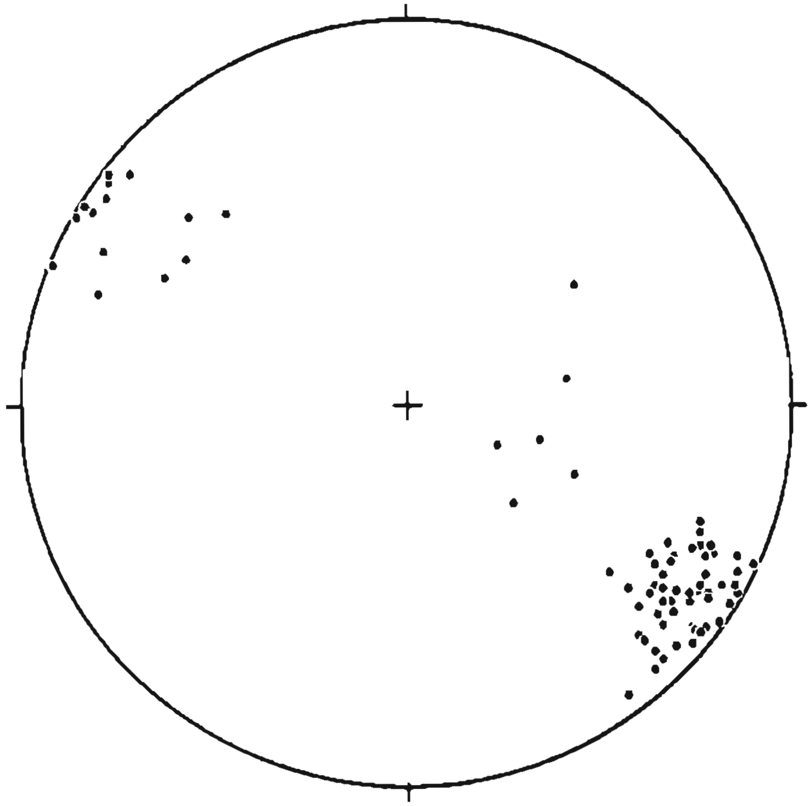

Figure 4. Poles to bedding planes, map area III

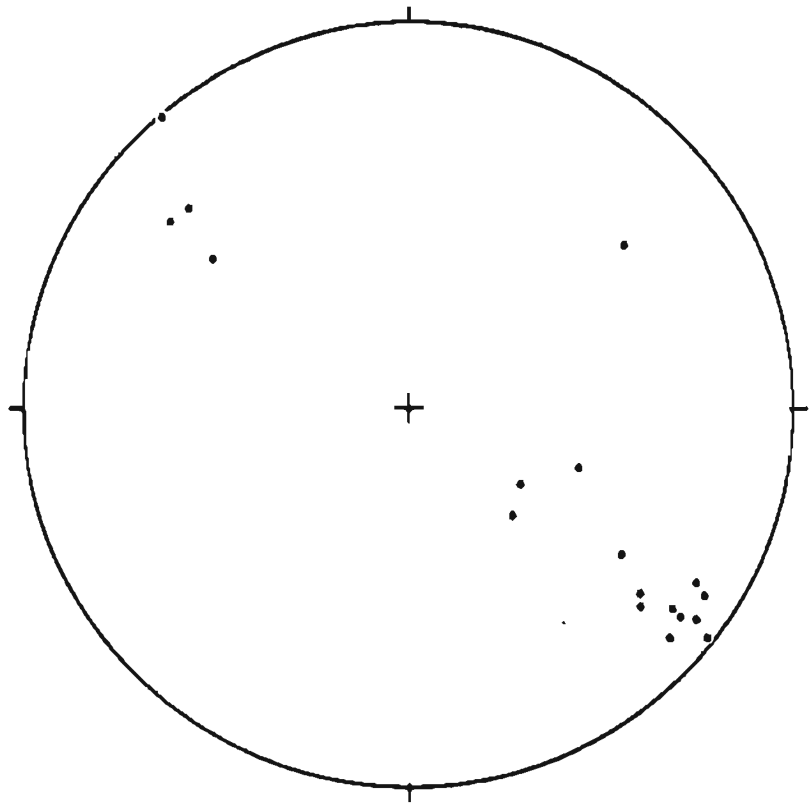

Figure 5. Poles to cleavage planes, map area I (excluding areas II and III)

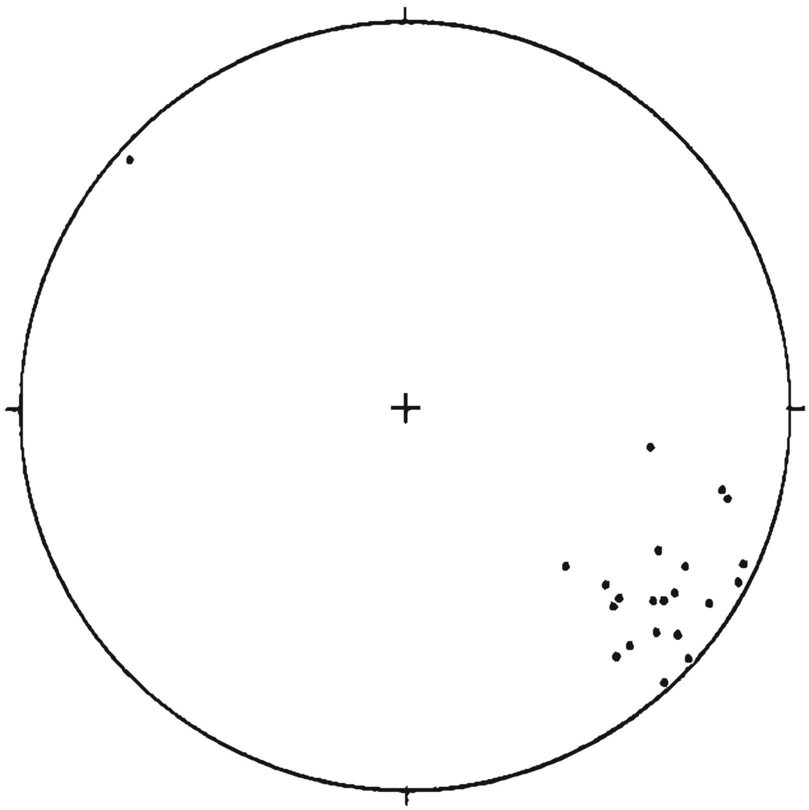

Figure 6. Poles to cleavage planes, map area II

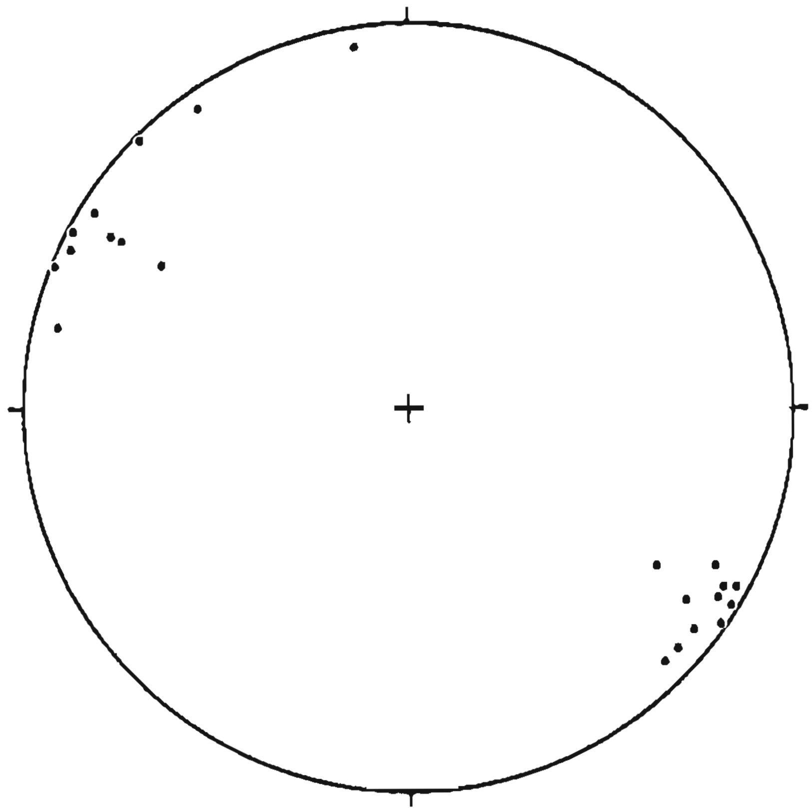

Figure 7. Poles to cleavage planes, map area III

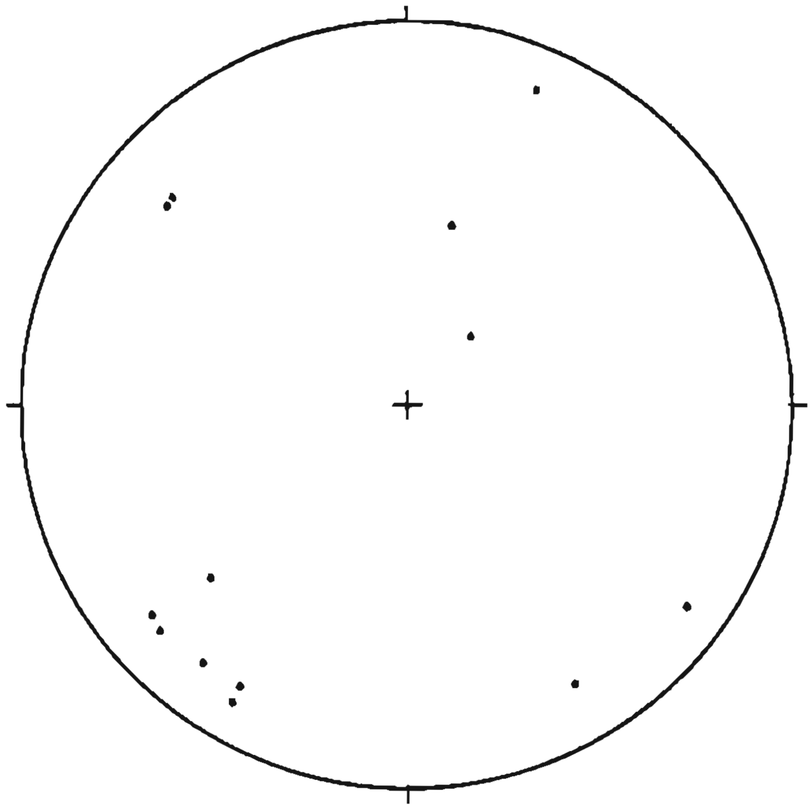

Figure 8. Fold axes orientations, map areas I, II and III

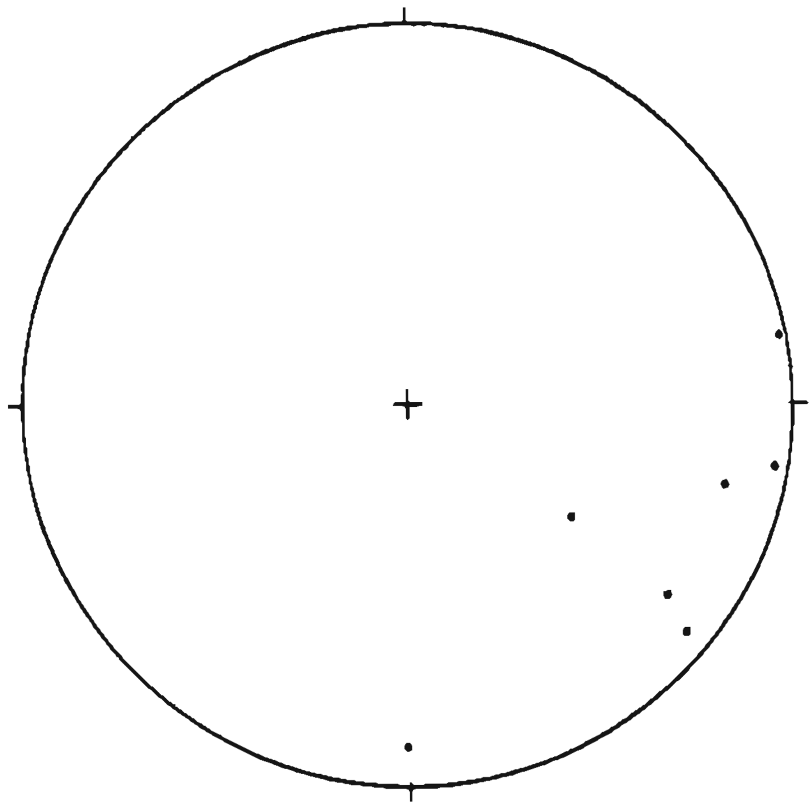

Figure 9. Poles to fault planes, map areas I, II and III

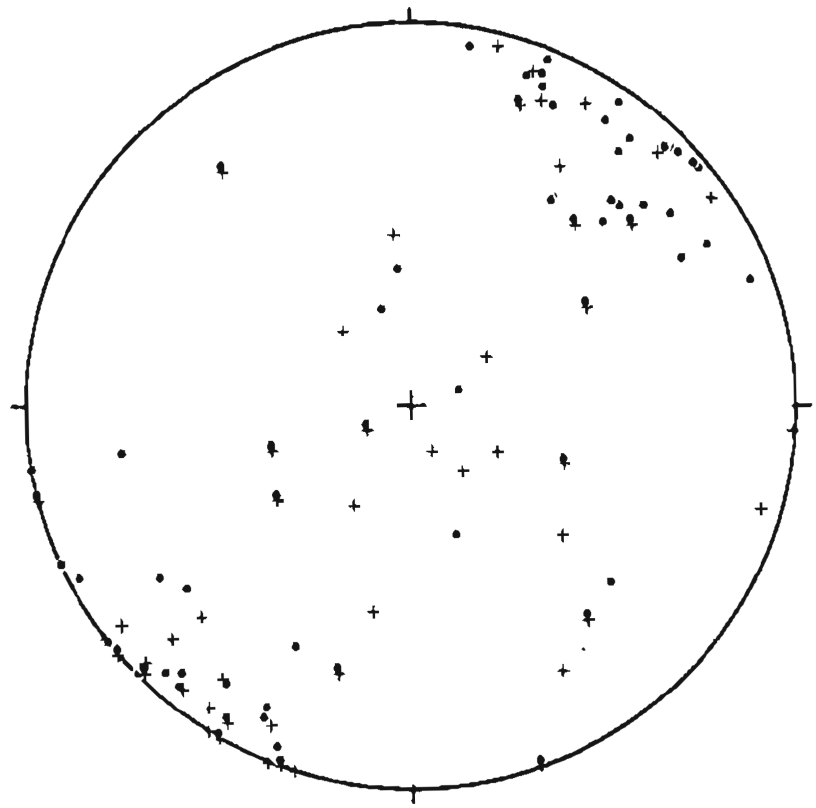

Figure 10. Poles to fracture planes, map area I (excluding areas II and III).
Dots are closely spaced, crosses are widely spaced fractures.

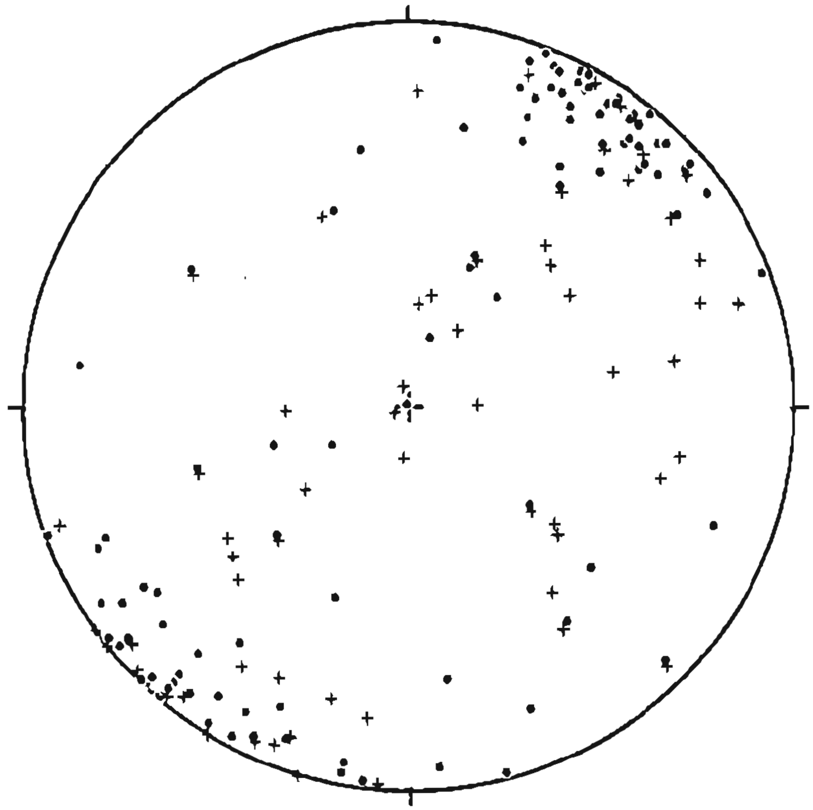

Figure 11. Poles to fracture planes, map area II. Dots are closely spaced, crosses are widely spaced fractures.

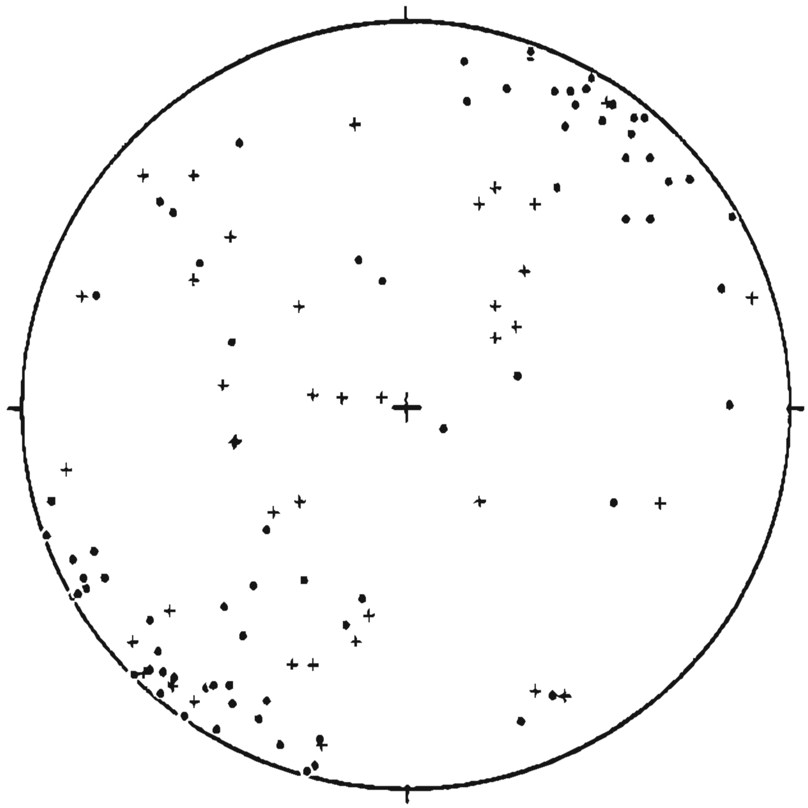

Figure 12. Poles to fracture planes, map area III. Dots are closely spaced, crosses are widely spaced fractures.

APPENDIX 1

Bedrock structural data. These data are plotted on Plates 1, 2, and 3.

STATION #	AREA	BEDDING	CLEAVAGE	FRACTURE	SPACING	OTHER	COMMENTS
88DNS200	III	47 58 SE	30 75 SE	30 75 SE	Fine-grained ss.		
							Axial planar cleavage.
88DNS201	III	25 90		322 30 SW	mod-wide	315 85 SW	Quartz vein
88DNS202	III	32 85 SE		290 60 NE	mod-wide	10 90	Quartz veins
				305 85 SW	v.close		
88DNS203	III	30 85 NW		300 80 SW	ext.close-close		
88DNS204	III					355 20 SW	Quartz veins
88DNS205	III	35 90	35 90				
88DNS206	III	32 90	32 90	300 80 NE	ext.close-mod.		
				32 55 SE	mod-wide		
88DNS207	III	30 90		305 80 NE	close		
88DNS208	III	45 85 NW		315 80 SW	ext close-mod.		
				45 55 SE	mod-wide		
88DNS209	III	30 80 NW				90 80 N	Fault
88DNS210	III			345 25 SW			
				315 80 NE			
88DNS211	III	25 85 NW		305 90	close-mod		
				290 48 SW	mod-wide		
88DNS212	III			310 52 NE	close-mod		
				310 40 SW	mod-wide		
88DNS213	III	32 83 NW					
88DNS214	III	42 85 NW		280 45 NE	wide	42 85 NW	Quartz veins
				320 30 NE	close-wide		
88DNS215	III	22 72 NW		304 78 NE	close-mod		
				282 43 NE	close-mod		
88DNS216	III			300 88 NE	close-mod	23 12	Fold axis
						22 77 SE	Axial plane
88DNS217	III	36 70 NW					
88DNS218	III	53 86 NW	53 86 NW	345 85 NW	close-mod		
88DNS220	I	63 21 NW		290 84 SW	wide		
				346 90	mod-wide		
88DNS221	I	17 58 NW		52 68 SE	mod-wide		
88DNS222	I		35 58 NW	50 62 NW	wide		
				312 55 SW	wide		
				335 10 NE	wide		
88DNS223	I	37 50 SE		320 90			
				325 35 NE			
88DNS224	I	32 80 NW		300 90	close-mod		
				343 31 NE	wide		
88DNS225	I	30 86 NW		324 69 NE	very close		
				330 45 SW	wide		
				20 35 NW	wide		
88DNS226	I	37 75 NW		285 61 NE	mod		
				290 74 SW	mod		
88DNS227	I	47 74 SE				45 70	Fold axis
88DNS228	I	27 88 NW		304 90	very close-mod		
88DNS229	I		38 90			218 15	Fold axis
88DNS230	I	60 75 SW		324 60 SW	mod-wide		
88DNS231	I			300 90			
88DNS232	I	36 75 NW		300 90	mod-wide		
88DNS233	I		46 33 NW	317 90	close-mod		
				34 84 SE	close-mod		
88DNS234	I	41 70 NW	20 40 NW	300 85 NE	wide		
88DNS235	I	47 88 SE		295 60 NE	close-mod		
88DNS236	I	35 72 NW		42 60 NW	close-mod		

STATION #	AREA	BEDDING	CLEAVAGE	FRACTURE	SPACING
				315 88 NE	wide
88DNS237	I	40 88 SE			
88DNS238	I	48 20 NW			
88DNS239	I	42 37 NW		60 68 NW	wide
				302 90	wide
				26 21 NW	wide
88DNS240	I	22 33 NW		16 85 NW	wide
				288 90	mod
88DNS241	I	15 20 NW		323 90	
88DNS242	I	20 52 NW		294 80 NE	mod-wide
		57 52 NW			
88DNS243	I	35 48 NW		316 86 NE	wide
88DNS244	I	51 78 NW		321 88 SW	v.close-mod
				50 18 NW	wide
88DNS245	I	46 74 NW		325 86 SW	mod
88DNS246	I	55 68 NW			
88DNS247	I	45 85 NW		302 64 SW	mod-wide
88DNS248	I	36 90			
88DNS249	I	37 85 SE	37 53 SE	305 75 NE	wide
88DNS250	I	28 84 NW		323 84 NE	wide
				40 43 NW	wide
88DNS251	I	36 80 NW	35 30 NW	295 77 NE	close-mod
88DNS252	I	30 70 NW			
88DNS253	I	39 86 NW	39 68 NW	290 90	mod
88DNS254	I	35 70 NW		300 82 SW	
88DNS255	I	31 90		288 90	
88DNS256	I	37 90			
88DNS257	II	35 65 SE		294 86 SW	v.close-mod
88DNS258	II	42 53 NW		294 64 SW	close-mod
88DNS259	II	22 86 NW		282 63 SW	close-mod
88DNS260	III	26 75 NW		314 86 NE	close-mod
				8 40 SE	wide
88DNS261	III	28 60 SE		305 63 NE	mod
				302 54 SW	mod-wide
88DNS262	III	27 77 SE		312 84 NE	close-mod
				282 52 NE	wide
88DNS263	III	20 74 SE	13 83 SE	290 84 NE	close
88DNS264	III	34 58 SE		284 88 NE	ext.close-mod
				65 70 NW	mod-wide
88DNS265	III			360 74 W	
				70 78 NW	
88DNS266	III	36 72 NW		292 53 SW	wide
				42 82 SE	wide
				330 90	close-mod
88DNS267	III	41 70 NW	82 84 SE	320 83 NE	mod
				73 33 SE	close-mod
88DNS268	III			9 20 SE	wide
88DNS269	II	22 70 NW	10 55 NW	290 80 NE	mod-wide
				315 44 SW	wide
88DNS270	III	33 84 NW	33 67 NW	303 86 SW	wide
				350 37 NE	wide
				284 80 NE	wide
				45 32 SE	wide
88DNS271	II	38 84 NW	45 50 NW	314 84 SW	
88DNS272	III	33 67 NW		342 85 SW	wide
				61 75 NW	close
88DNS273	III			340 78 SW	close
				48 72 SE	mod

STATION #	AREA	BEDDING	CLEAVAGE	FRACTURE	SPACING	OTHER	COMMENTS
88DNS274	III	40 88 NW		310 89 NE	close		
88DNS275	III	41 78 NW		332 85 NE	close-mod		
88DNS276	I	38 58 NW	38 80 NW	309 84 NE	mod-wide		
88DNS277	I	32 67 NW	32 78 NW	304 84 NE	mod-wide		
				50 22 SE	wide		
88DNS278	I	38 65 NW	38 80 NW	320 90	wide		
88DNS279	I	41 70 NW	41 70 NW				
88DNS280	I	37 63 NW	37 84 NW	316 76 NE			
88DNS281	I	42 70 NW		292 90			
88DNS282	II	31 68 NW		322 89 NE			
88DNS283	I	45 84 NW		314 83 SW	mod		
88DNS284	I			293 77 SW	mod		
				3 90	mod-wide		
88DNS285	I	45 55 SE		315 67 NE	mod-wide		
				65 10 NW	mod-wide		
88DNS286	II	26 86 NW		75 90	close-mod		
				80 5 SE	wide		
88DNS287	II	42 75 NW	42 86 SE	303 69 NE	wide		
88DNS288	I	40 80 NW		320 65 SW	close		
				320 65 NE	mod		
88DNS289	I	25 60 NW		284 88 SW	mod-wide		
88DNS290	I	42 83 NW		291 86 NE	close-mod		
				305 56 SW	close-mod		
88DNS291	I	32 87 SE		290 90	close-wide		
				300 24 NE	mod		
				310 65 SW	mod-wide		
88DNS292	II	42 70 NW		310 68 SW			
				295 32 SW			
88DNS293	II	36 74 NW		318 75 NE			
				54 60 NW			
88DNS294	II	34 72 NW		308 85 NE	mod		
88DNS295	II	29 52 NW	37 74 NW	310 68 SW	ext.close-mod		
				343 30 NE	close-mod		
88DNS296	II	21 56 NW	16 77 NW	311 88 NE	close-mod		
				45 85 NW	wide		
88DNS297	II	35 44 NW				35 44 NW	Fault
						230 15	Fold axis
						325 85 SW	Quartz veins
88DNS298	II	32 48 NW	38 72 NW	310 90	ext.close-mod		
88DNS299	II	22 52 NW	15 75 NW	322 28 NE	wide	15 75 NW	Fault
				287 90	mod-wide		
88DNS300	II	47 62 NW	42 90	333 75 SW	wide		
				296 67 NE	wide		
88DNS301	II	37 74 NW	37 74 NW	310 78 SW			
88DNS302	II	37 82 NW		313 90	close-mod		
88DNS303	II	37 47 NW	44 65 NW	315 75 SW	close-mod		
88DNS304	II	30 34 NW	30 66 NW	305 65 NE		210 10	Fold axis
				276 23 SW	wide		
88DNS305	II	18 43 NW	35 75 NW	304 80 SW		210 15	Fold axis
88DNS306	II	22 83 NW		307 74 SW	mod		
88DNS307	II			297 80 SW			
88DNS308	II	34 45 NW	30 74 NW	318 78 SW	ext.close-mod		
88DNS309	II	24 55 NW		313 90	v.close-mod		
88DNS310	II		40 83 NW	307 84 NE	close-mod		
				310 30 SW	v.close-mod		

STATION #	AREA	BEDDING	CLEAVAGE	FRACTURE	SPACING	OTHER	COMMENTS
88DNS311	II		47 90	314 90	ext.close-mod		
				290 15 SW	v.close-mod		
88DNS312	II	42 65 NW	42 65 NW	336 75 NE	close		
88DNS313	II	23 80 NW		305 87 SW	close		
88DNS314	II	39 79 NW		305 86 SW	wide		
				303 20 SW	wide		
88DNS315	II	38 58 NW		313 80 SW	wide		
				275 10 NE	wide		
88DNS316	II	45 76 NW		310 85 SW	close		
88DNS317	II	31 76 NW		315 40 NW	mod		
				302 88 NE	ext.close-mod		
88DNS318	II	33 81 NW		316 88 NE	mod		
88DNS319	II	25 70 NW		292 84 NE	mod		
88DNS320	II	34 73 NW					
88DNS321	II	38 88 NW		310 78 SW	v.close-close		
				332 18 NE	close-mod		
88DNS322	II	38 78 NW		324 74 SW	mod		
88DNS323	II	28 28 NW		310 90	v.close		
88DNS324	II	39 77 NW					
88DNS325	II	45 79 NW		322 90	mod		
				360 26 E	mod-wide		
				38 40 NW	mod-wide		
88DNS326	II	45 80 SE		310 88 NE	mod		
88DNS327	II	43 79 NW		325 43 SW	mod		
88DNS328	II	32 76 NW		314 72 SW	mod		
88DNS329	II	52 76 NW		325 90	mod-wide		
88DNS330	II	20 90		300 88 SW	mod-wide		
88DNS331	II	35 80 NW		304 84 SW	close		
88DNS332	II	45 78 NW		302 90	mod-wide		
				66 46 SE	mod		
88DNS333	III	28 67 NW	28 88 SE	315 87 NE	mod-wide	227 14	Fold axis
				320 70 NE	mod		
88DNS334	III	41 64 SE	45 88 SE	350 79 NE	mod-wide		
				12 14 SE	wide		
88DNS335	III	22 89 SE	22 89 SE	321 25 SW	wide		
				310 84 NE	mod-wide		
				294 62 NE	wide		
88DNS336	III	26 79 NW		306 84 NE	mod-wide		
88DNS337	II	30 60 NW		310 47 SW	wide		
				310 80 SW	v.close-mod		
88DNS338	II	36 56 NW		299 78 SW	v.close-mod		
88DNS339	II	47 80 NW		308 86 SW	mod		
88DNS340	II	43 81 NW		305 59 SW	mod		
				10 61 NW	wide		
88DNS341	II	45 58 NW		320 84 NE	close-mod		
88DNS342	II	28 70 NW		308 84 SW	close		
88DNS343	II	40 80 SE		323 71 NE	v.close-mod		
88DNS344	II	35 90		290 77 SW	close-mod		
88DNS345	II	25 65 NW	25 88 NW				
88DNS346	II	28 50 NW	28 89 NW	340 90			
88RR200	III	25 85 NW	25 86 SE	20 80 SE	mod	35 47	Paleocurrent
		35 80 NW		285 90	close-mod		

STATION #	AREA	BEDDING	CLEAVAGE	FRACTURE	SPACING	OTHER	COMMENTS
		35 88 SE		285 50 NE	mod		overturned beds
				80 65 SE			
88RR201	III		30 85 NW	288 76 SW	mod		
				310 30 SW			
				40 68 SE	close		
				20 60 NW	mod		
88RR202	III	32 85 SE	32 85 SE	300 85 SW	close-mod	85 72 SE	Quartz veins
		45 85 NW	45 85 NW	40 72 SE			
		45 77 NW	28 80 NW	322 85 SW	close-mod		
		37 88 NW	32 85 NW	295 80 NE	close-mod		
		30 80 NW		320 80 SW	close-mod		
				300 73 SW	close-mod		
				300 44 NE			
				330 86 NE			
88RR203	III	29 88 NW	35 78 NW	315 90	close-mod		
		30 88 SE	30 63 SE	20 79 SE	mod	240 58	slickensides
			42 85 NW	335 79 NE	close		
			29 88 NW	25 51 NW	close-mod		
				302 76 NE	close-mod		
				298 82 SW	close-mod		
				310 85 NE	close-mod		
				30 6 SE	mod		
88RR204	III	37 86 SE		330 88 NE	close-mod	149 15	Fold axis
88RR205	III	30 86 NW		305 59 SW	close-mod		
				35 55 SE	close-mod		
88RR206	III	38 85 NW	38 85 NW	290 85 NE	close-mod		
88RR207	III	37 76 NW		310 88 SW	close-mod		
		30 85 NW		350 38 NE		305 80 SW	Quartz veins
88RR208	III	27 87 NW		323 70 SW	close-mod		
				300 88 SW	close-mod		
				310 88 SW			
				50 25 NW			
88RR209	III	35 75 NW		320 76 NE	close-mod	15 50	Fold axis
		40 65 NW		32 10 NW	close-mod		
				323 36 NE	wide		
88RR210	III	27 77 NW		280 80 SW	close-mod		
		22 72 NW		318 40 NE	close-mod		
		32 80 NW		282 70 SW	close-mod		
		24 73 NW		20 40 SE	close-mod		
		25 77 NW					
88RR211	III	27 73 NW		290 86 SW	close-mod		
		32 88 SE		310 85 NE	close-mod		
		30 70 NW		80 27 SE	close-mod		
				312 60 NE	close		
				63 75 NW	close-mod		
88RR212	III	34 79 NW		309 86 SW	close-mod	248 68	Loadcasts
		35 84 SE		310 83 NE			
				320 65 SW			
88RR213	III	40 75 NW		312 76 SW	close		
88RR214	III	40 83 SE		295 75 NE	close		
				340 90	close-mod		
				330 88 NE			
88RR215	I	38 67 SE	42 82 NW	303 77 NE	close-mod		
		33 66 NW	38 67 SE	75 21 SE	close-mod		
		36 68 NW	33 82 NW	310 82 NE	close-mod		
				305 55 SW	close-mod		
				320 70 SW			
				292 83 SW			
88RR216	I	40 84 NW		320 88 SW	close-mod	328 62 SW	Quartz vein
		42 80 NW		317 65 SW			

STATION #	AREA	BEDDING	CLEAVAGE	FRACTURE	SPACING	OTHER	COMMENTS
		42 72 NW		317 60 SW			
		58 84 NW		335 90	close-mod		
		57 84 NW		293 80 SW	close-mod		
		62 70 NW		296 76 SW			
		46 75 NW					
		57 89 NW					
		27 37 SE					
88RR217	I	48 88 NW		316 86 SW			
		52 88 NW		309 85 NE	close-mod		
		47 86 NW					
		32 88 SE					
88RR218	I	30 77 NW	50 89 SE	290 81 SW	close-mod		
		50 45 NW		305 85 SW	close-mod		
		30 68 SE		317 86 SW	close-mod		
		45 68 NW		340 85 SW			
		40 61 SE		295 80 NE			
		40 72 SE		315 65 SW			
		42 85 NW		315 90			
		45 79 NW		280 85 SW			
		44 87 NW		305 80 SW			
		45 82 NW					
88RR219	I	43 83 NW		332 78 SW	close-mod	126 10	Fold axis
		35 79 SE		345 11 SW	close	54 70 SE	Axial plane
		55 70 SE		324 74 SW		332 78 SW	Quartz veins
		39 88 NW		350 90		345 11 SW	Quartz veins
		35 80 SE		310 75 SW			
		38 90		315 88 NE			
		42 80 NW		310 80 SW	close-mod		
		42 89 NW					
		40 85 NW					
88RR220	II	38 85 SE		320 86 NE	close	310 60 SW	Quartz veins
88RR221	III	38 70 NW		296 80 SW	close	97 63	Slickensides
		352 35 SW		25 80 SE		310 20	Fold axis
		23 40 NW		58 70 SE		332 62 SW	Quartz veins
		40 59 NW		335 85 NE	close	350 89 SW	Fault plane
		25 22 NW		305 85 SW		320 25	Fold axis
		15 30 NW		330 80 NE			
		325 45 SW					
		43 32 NW					
		31 70 NW					
		47 85 NW					
		38 86 NW					
		45 82 NW					
88RR222	II	32 80 NW	47 75 NW	42 54 NW		104 14	Slickensides
		36 76 NW		285 67 NE		312 20	Fold axis
		28 68 SE		70 45 SE			
		48 85 SE		335 15 SW			
		35 70 SE		32 56 SE	mod		
		40 68 NW		300 84 SW			
		30 88 SE		300 85 SW			
		20 65 NW					
		30 77 NW					
		60 66 NW					
		55 70 NW					
88RR223	II	30 89 NW	42 60 NW	278 70 NE	wide		
88RR224	II	32 75 NW		52 51 NW	wide		
88RR225	III	38 74 NW	30 78 SE	290 88 SW			
88RR226	III	34 70 NW	55 84 SE			228 32	Fold axis
						40 88 NW	Axial plane
88RR227	III	38 78 NW		284 80 NE			

STATION #	AREA	BEDDING	CLEAVAGE	FRACTURE	SPACING	OTHER	COMMENTS
88RR228	II	42 78 NW	42 78 NW	303 63 SW	close		
		38 74 SE		320 50 NE			
88RR229	I	41 69 NE		325 69 NE	close		
		50 72 SE	42 66 SE	85 29 SE	close-mod		
		41 52 SE		300 85 NE	close		
		40 52 SE		350 65 NE	close		
		38 68 NW		332 70 SW			
		40 60 SE		280 45 NE			
				315 85 SW			
				312 85 NE			
				85 38 SE			
88RR230	II	35 70 NW		290 82 SW	mod		
				340 70 SW	mod		
88RR231	II	40 70 NW		320 85 SW	mod		
				290 85 SW	close-mod		
88RR232	I	42 87 SE		332 87 NE	close		
88RR233	I	35 89 SE		292 87 SW	close		
				70 30 NW	close		
88RR234	II	45 48 NW	50 75 NW	325 48 NE	mod	98 22	Slickensides
		25 50 NW		320 88 NE	close		
		45 75 NW		290 85 NE	close-mod		
		30 65 NW		343 48 NE			
		30 45 NW		85 85 NW			
		40 48 NW		315 77 SW	close		
				272 72 SW	mod		
				312 80 SW			
				275 85 SW	close		
				310 88 NW	close-mod		
88RR235	II	38 83 NW		310 82 NE	close		
88RR236	II	35 70 NW		340 89 SW	close		
88RR237	II	40 83 NW		300 75 SW	close		
				350 60 SW			
88RR238	II	20 47 NW					
88RR239	II	45 80 NW					
88RR240	II	20 73 NW		275 88 NW	mod		
				293 76 SW			
88RR241	II	33 63 NW		305 85 SW	close		
88RR242	II	20 78 NW		277 89 NE	close		
				315 53 NE	mod		
88RR243	II	30 68 NW		280 85 NE	close		
88RR244	II	30 78 NW		298 88 NE		10 88 NW	Fault plane
88RR245	II	15 77 NW		295 85 NE	close		
88RR246	II	40 74 NW		15 58 NW	mod		
				310 85 NE	close		
88RR247	II	45 68 NW		7 75 SE			
88RR248	II	25 65 NW		82 62 NW	close-mod		
88RR249	II	42 77 NW		342 80 SW	mod		
				320 85 NE	close		
88RR250	II	34 88 SE		295 85 NE	mod		
88RR251	II	44 84 NW		327 85 NE			
88RR252	II	27 64 NW		290 45 NE	close		
88RR253	II	26 88 NW		342 85 NE	wide		
				325 75 SW	close		
88RR254	II	26 82 NW		298 88 SW			
88RR255	II	35 65 NW		293 70 SW	close		
				282 25 SW	wide		
88RR256	II			298 80 NE			
88RR257	II	32 75 NW	33 85 NW	320 85 SW	close		
88RR258	II	35 55 NW		303 80 NE			
88RR259	II	45 65 NW		325 73 NE			

STATION #	AREA	BEDDING	CLEAVAGE	FRACTURE	SPACING	OTHER	COMMENTS
88RR260	II	38 67 NW		292 89 SW	close		
88RR261	II	24 70 NW		310 89 SW	close		
				295 35 SW			
88RR262	II	38 78 NW		313 88 NE			
88RR263	II	40 82 NW		310 87 NE			
88RR264	II	39 84 NW		299 88 SW	close		
88RR265	II	45 77 NW		290 82 NE	close		
88RR266	II	25 84 NW		295 85 SW	close		
88RR267	II	20 88 NW		298 85 SW	close		
88RR268	II	28 85 NW		305 85 SW	close		
88RR269	II	38 88 SE		330 89 SW	close		
88RR270	II	38 88 NW		310 82 SW	close		
88RR271	II	39 80 NW		325 80 NE	close		
88RR272	II	36 80 NW		335 78 NE	close		
88RR273	II	42 82 SE		320 85 NE			
88RR274	II	36 64 NW		310 74 NE	close		
				80 57 SE	close		
				40 34 NW	mod		
88RR275	II	30 76 NW		295 80 SW	close	244 23	Slickensides
				68 75 NW			
				55 60 NW	mod		
88RR276	II	45 65 NW		40 42 NW	mod	40 85 NW	Fault plane
				315 86 SW			
88RR277	II	31 68 NW		290 85 SW	close		
88RR278	II	40 75 NW		325 85 SW	close		
88RR279	II	25 88 NW		293 75 NE	close		
88RR280	II	38 85 NW		320 87 SW	close		
				350 45 SW	wide		
88RR281	I			325 20 SW	mod		
88RR282	II	37 88 NW		280 88 NE			
88RR283	II	48 60 NW	22 75 NW	325 85 SW			