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Paleomagnetism and Tectonic Significance of the Goble Volcanics of Southern Washington

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PALEOMAGNETISM AND TECTONIC SIGNIFICANCE OF THE GOBLE VOLCANICS OF SOUTHERN WASHINGTON

by

Cynthia D. Burr

Accepted in Partial Completion
of the Requirements for the Degree
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MASTER'S THESIS

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PALEOMAGNETISM AND TECTONIC SIGNIFICANCE OF THE GOBLE VOLCANICS OF SOUTHERN WASHINGTON

A Thesis

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The Faculty of

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ABSTRACT

The upper Eocene to lower Oligocene Goble Volcanic series of southwest Washington is a thick sequence of areal to submarine basaltic to andesitic flows, pyroclastics, and minor sediments. Major element geochemical analyses suggest that these rocks may represent early magmatism of the Cascade arc. Paleomagnetic results from 37 sites indicate that the direction of remanent magnetization in the Goble Volcanics has a declination of 18.5°, an inclination of 57.5°, and a circle of 95% confidence (α_{95}) of 4.33°. The expected upper Eocene direction in the sampling area is $\overline{D}$ = 353.5°; $\overline{I}$ = 61.5°. Thus the Goble Volcanics block appears to have rotated approximately 25° in a clockwise direction relative to the North American interior since the late Eocene. Comparison of this result with those of Cox, Simpson, and Plumley for the Oregon Coast Range, which show an apparently greater degree of rotation, suggests that the Goble Volcanics are not part of the Coast Range block. This also is supported by geochemical and geophysical differences between the provinces.

Simpson (1977) has proposed two models to explain the Coast Range rotation. Model I assumes that the block extends to the Olympic Mountains and rotated seaward around its northern end in response to extension from behind. Model II assumes the block did not extend as far as the Olympic Mountains, and that it rotated around a pivot point at its southern end. Both models have major problems, which are compounded by results from the Goble Volcanics.

Two possible models for rotation of the Goble Volcanics as part of an independent block have been examined. These are: (1) the "ball-bearing model", in which an equant block rotates between right-lateral faults

in a large continental shear zone; and (2) the "Fitch model", wherein an equant block rotates between a subduction zone and a transcurrent fault pair formed in response to oblique subduction. A preferred but very tentative model proposed in this thesis to explain rotation in both the Goble and Coast Range blocks is a revised model I. It assumes a break in the Coast Range block near the Columbia River. The Coast Range would then rotate around a pivot point in the Tillamook highland area. The Goble Volcanics, which would lie northeast of the rotating block, might then rotate independently in a "ball-bearing" fashion between right-lateral strike-slip faults trending northwest-southeast. These faults, including the Brothers, Eugene - Denio, Vale and Portland fault may have formed in response to basin and range extension. In particular, the Portland fault which may extend through the Coast Range block, and possible faults to the north parallel to the Olympic - Wallowa lineament may have been responsible for the rotation of the Goble Volcanics.

ACKNOWLEDGEMENTS

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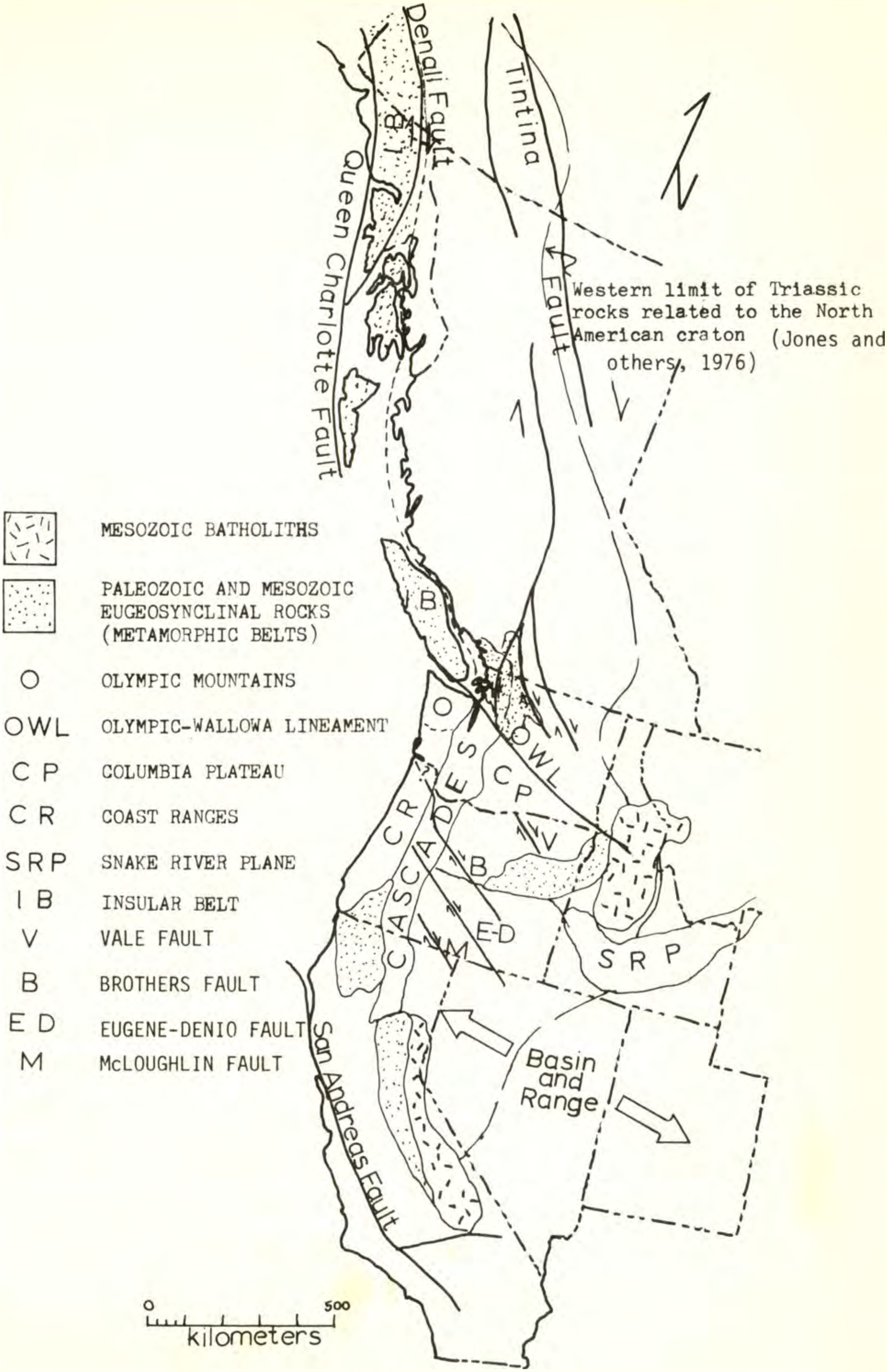
INTRODUCTION

The tectonic development of the westernmost Cordillera between California and Alaska has remained enigmatic, even with the advent of the plate tectonics model. This region has undergone a long history of plate interactions producing a complicated combination of geologic features and provinces, including the Columbia River Plateau, the Olympic-Wallowa lineament, the Basin and Range province, the Cascades, and possible allochthonous crustal blocks such as the Oregon-Washington Coast Range and the Insular belt of British Columbia (see figure 1).

Paleomagnetic studies by Simpson and Cox (1977) and Plumley and Beck (1977) on Eocene and Oligocene rocks in the Oregon Coast Range have shown that as much as 65 degrees of clockwise rotation has occurred relative to North America since early Eocene time. Many other Mesozoic and Cenozoic rock units in the westernmost Cordillera also have yielded discordant directions (Packer and Stone, 1974; Beck, 1976; Hillhouse, 1977). Thus, rotation and/or translation of crustal blocks has played a major role in the evolution of this region. This process has come to be known informally as "microplate tectonics". Much more work in different areas and on rocks of different ages will be needed to evaluate the importance of microplate tectonics and unravel the complex history of plate interactions. The Goble Volcanic series of southwestern Washington, upon which this report is based, provides another example of a rotated block. The purpose of this investigation was to determine a paleomagnetic pole for the area, to see if it showed rotation, and if so, to compare it to rotations of rocks of similar age in adjoining areas. The results of this study put constraints on models used to explain

Figure 1. Generalized geologic and tectonic map of the Western North American Cordillera from California to Alaska. (from Churkin and Eberlein, 1977; Simpson, 1977; Davis, 1977; and Jones and others, 1976).


Denali Fault
Tintina Fault
Queen Charlotte Fault
I B
Western limit of Triassic rocks related to the North American craton (Jones and others, 1976)
B
O
OWL
CP
CR
CASCADES
V
E-D
M
SRP
Basin and Range
San Andreas Fault
MESOZOIC BATHOLITHS
PALEOZOIC AND MESOZOIC EUGEOSYNCLINAL ROCKS (METAMORPHIC BELTS)
O OLYMPIC MOUNTAINS
OWL OLYMPIC-WALLOWA LINEAMENT
C P COLUMBIA PLATEAU
C R COAST RANGES
SRP SNAKE RIVER PLANE
I B INSULAR BELT
V VALE FAULT
B BROTHERS FAULT
E D EUGENE-DENIO FAULT
M McLOUGHLIN FAULT
0 500
kilometers

the rotation found in the Oregon Coast Range directly west and southwest of the study area.

GEOLOGY

The Goble Volcanic series is an upper Eocene to lower Oligocene sequence of basaltic to andesitic flows, pyroclastics and minor sediments largely of subaerial origin. It crops out over an area of approximately 1700 square kilometers between longitudes 122°-123°W and latitudes 45°30'-46°30'N and may extend beneath younger sedimentary and volcanic rocks (figure 2). Although the Goble Volcanics comprise a large area in southwestern Washington, they have been studied very little. Wilkinson and others (1946) named and mapped the Goble Volcanics in the St. Helens Quadrangle, Oregon, and to the north along both sides of the Columbia River. Henriksen (1956) also described the Goble Volcanics which he classified as a member of the Cowlitz Formation in the lower Cowlitz River-eastern Willapa Hills area. Other than these two reports, and reconnaissance mapping by Gower and Livingston (1958) for the geologic map of Washington (1961), no other complete geological report has been done on the Goble Volcanics east of the Columbia River.

The late Eocene-early Oligocene age is based on faunal ages of the Cowlitz Formation, which interfingers with the basal flows of the Goble Volcanics west of the study area near Kelso-Longview. Goble rocks are largely a south- to southeast-dipping sequence of lava flows and pyroclastics. Thicknesses in excess of 1500 meters have been measured along the type section exposed on the Columbia River north of Portland, and the unit may increase in thickness to the east (Wilkinson and others, 1946). Individual flows range in thickness from less than one meter to more than

Figure 2. Geologic map of southwestern Washington showing distribution of the Goble Volcanics and locations of the paleomagnetic sites.

DISTRIBUTION of the GOBLE VOLCANICS in SW Washington and NW Oregon and Site Locality Map

LEGEND

QUATERNARY and PLIOCENE

- alluvium and sediments
- volcanic rocks

MIOCENE

- sedimentary rocks
- volcanic rocks

OLIGOCENE - MIOCENE

- sedimentary rocks and volcanic rocks

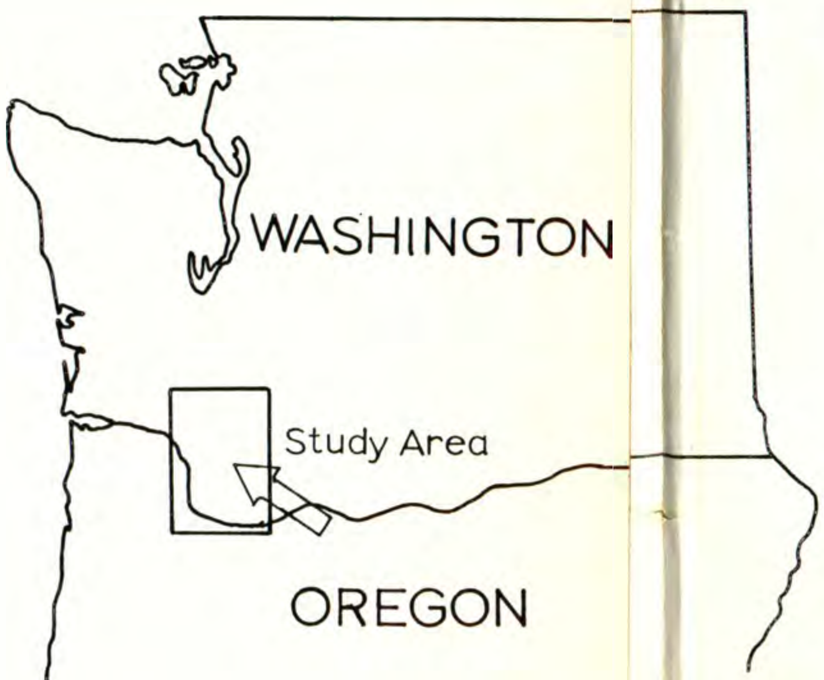
EOCENE - OLIGOCENE

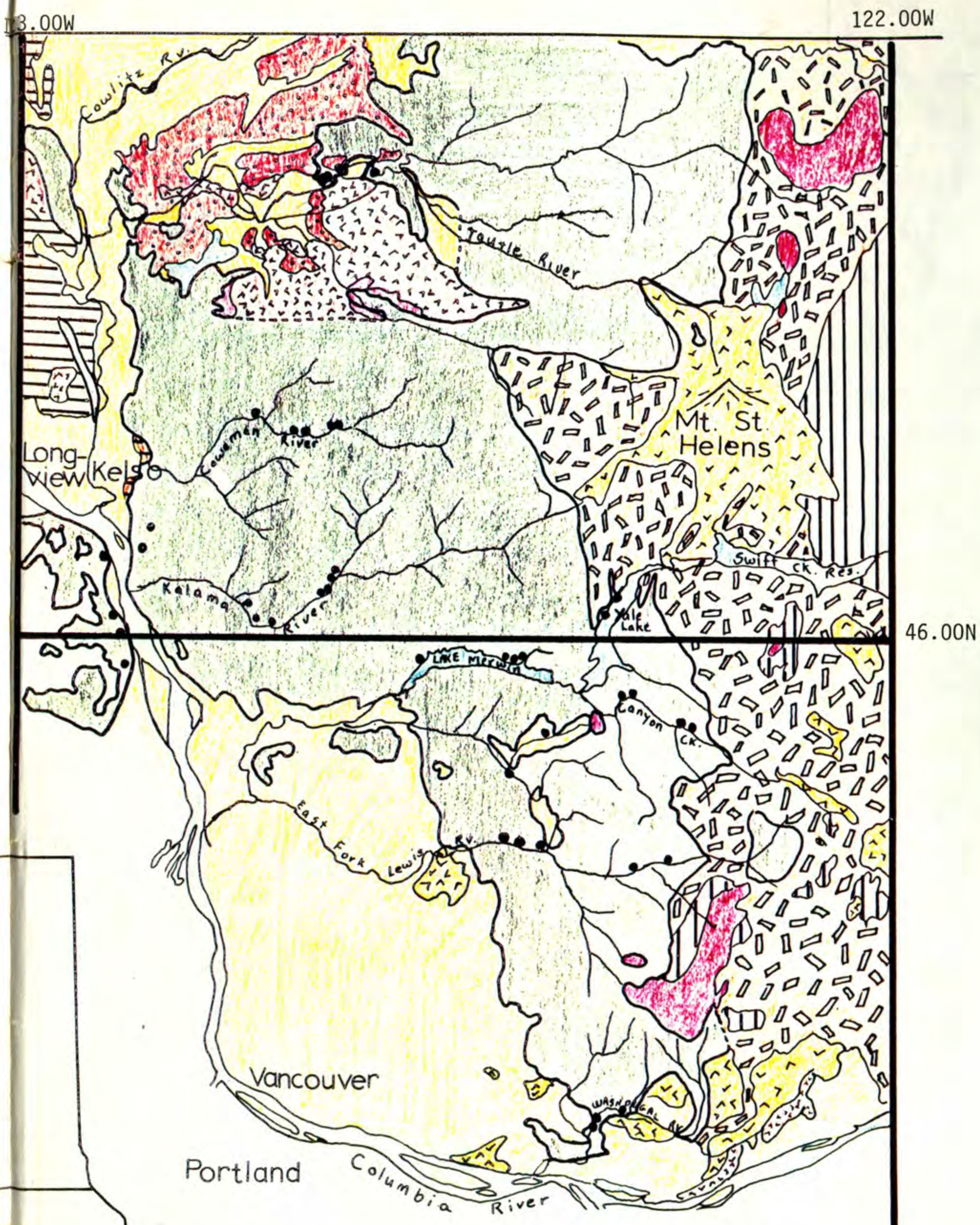
- volcanic rocks

EOCENE (UPPER)

- sedimentary rocks Cowlitz Formation
- Goble Volcanics
- undifferenciated TERTIARY intrusives

• Site Location





from: Geologic Map of Washington, 1961

Scale = $\frac{1}{500,000}$

0 10 20 30 40 Km

30 meters. Flows are typically massive basalt or basaltic andesite lying on a rubbly breccia base, which commonly forms irregular surfaces. Platy jointing parallel to flow surfaces is common in more siliceous flows, and rectangular or columnar jointing characterizes basalts. Abundant vesicles, amygdules and zeolites are also found in this rock unit and seem to characterize most upper Eocene basaltic sequences in southwestern Washington and northwestern Oregon. A photograph of a typical flow is shown in figure 3.

Figure 3. Typical basalt flow of Goble Volcanics from along the Kalama River. Note the reddish colored pyroclastic unit at the base of the flow.

In thin section the Goble Volcanics show considerable textural variation. All samples are hypocrystalline, highly feldspathic, and slightly to markedly porphyritic. Tabular plagioclase ranging in composition from andesine to bytownite is the dominant mineral in these rocks, comprising over 50 percent of each sample. Other essential constituents include augite, olivine, magnetite, volcanic glass, chloritic alteration products, and secondary minerals such as calcite. For a more detailed petrographic description see Wilkinson and others (1946) or Henriksen (1956).

Major element geochemical analyses of samples from 15 flows within the study area showed these rocks are sub-alkalic, and vary from high alumina, calc-alkaline rocks to arc tholeiites (figure 4). Nine of the ten samples having SiO_2 contents between 51-56% fall in the orogenic region of the discriminant diagram by Pearce, Gorman and Birkett (1977) shown in figure 5. Other extrusive rocks from the Cascades as well as two samples from the Yachats basalt are plotted for comparison. This diagram suggests that the Goble Volcanics are part of a volcanic arc complex and may be related to inception of Cascade arc volcanism. For the results of the geochemical analyses and a short discussion of the samples and geochemical techniques see appendix A.

Volcanic rocks of similar age and apparently similar lithology in Oregon include the Yachats basalt (Snavely and MacLeod, 1974), the Tillamook Volcanic series and the volcanics at Cascade Head in the Coast Ranges, and the Colestin Formation in the western belt of the southern Cascades (Peck and others, 1964); in Washington similar rocks include, the Unit B basalt along the Lower Columbia River in the Grays River area

Figure 4. (a) Silica versus soda diagram.

(b) Silica versus potash diagram showing fields occupied by the Goble Volcanics. (fields from Middlemost, 1975).

(c) Silica versus FeO/MgO for non-alkalic rocks. This composition shows that the Goble Volcanics are transitional between calc-alkaline and tholeiitic (fields from Miyashiro, 1974).

All chemical values have an error limit of ±5 percent.

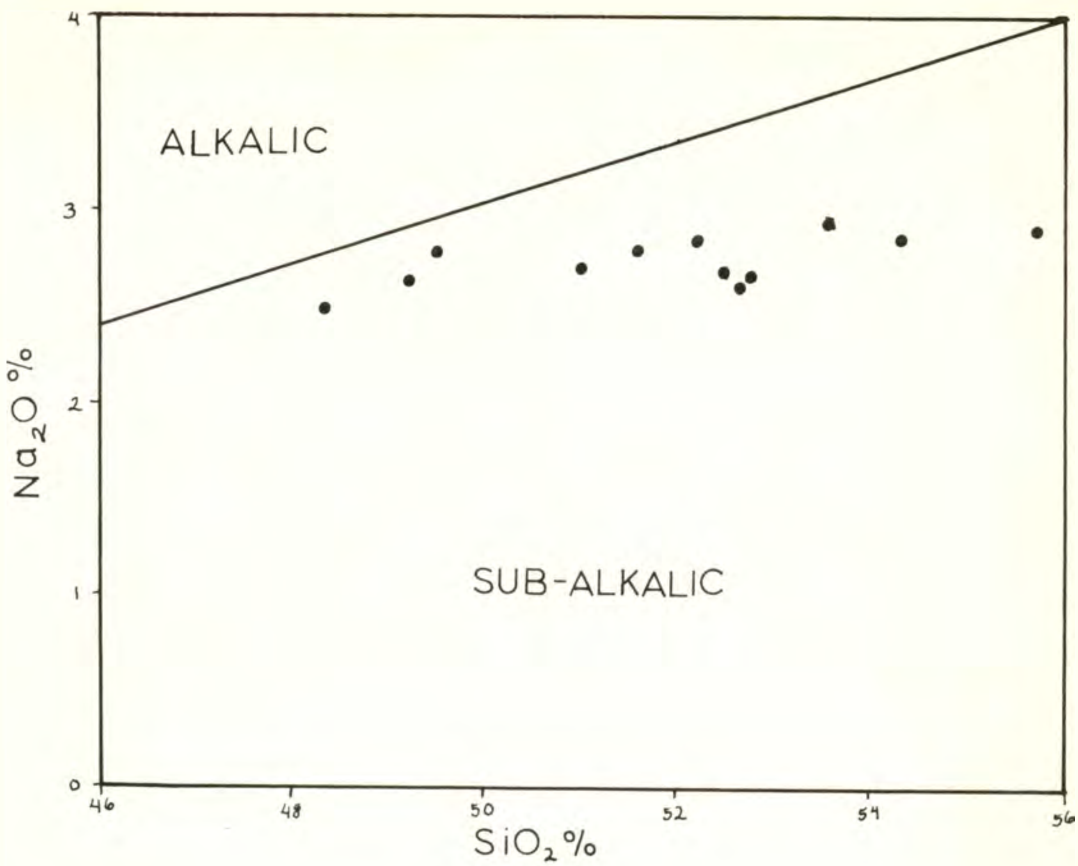


Figure 4a

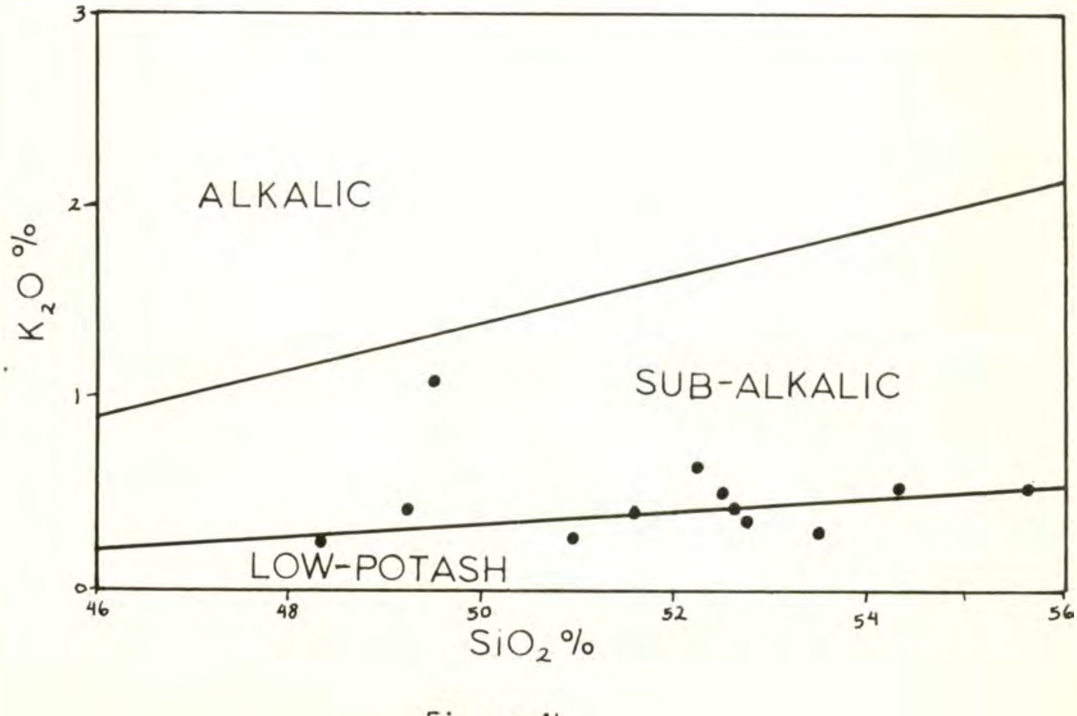


Figure 4b

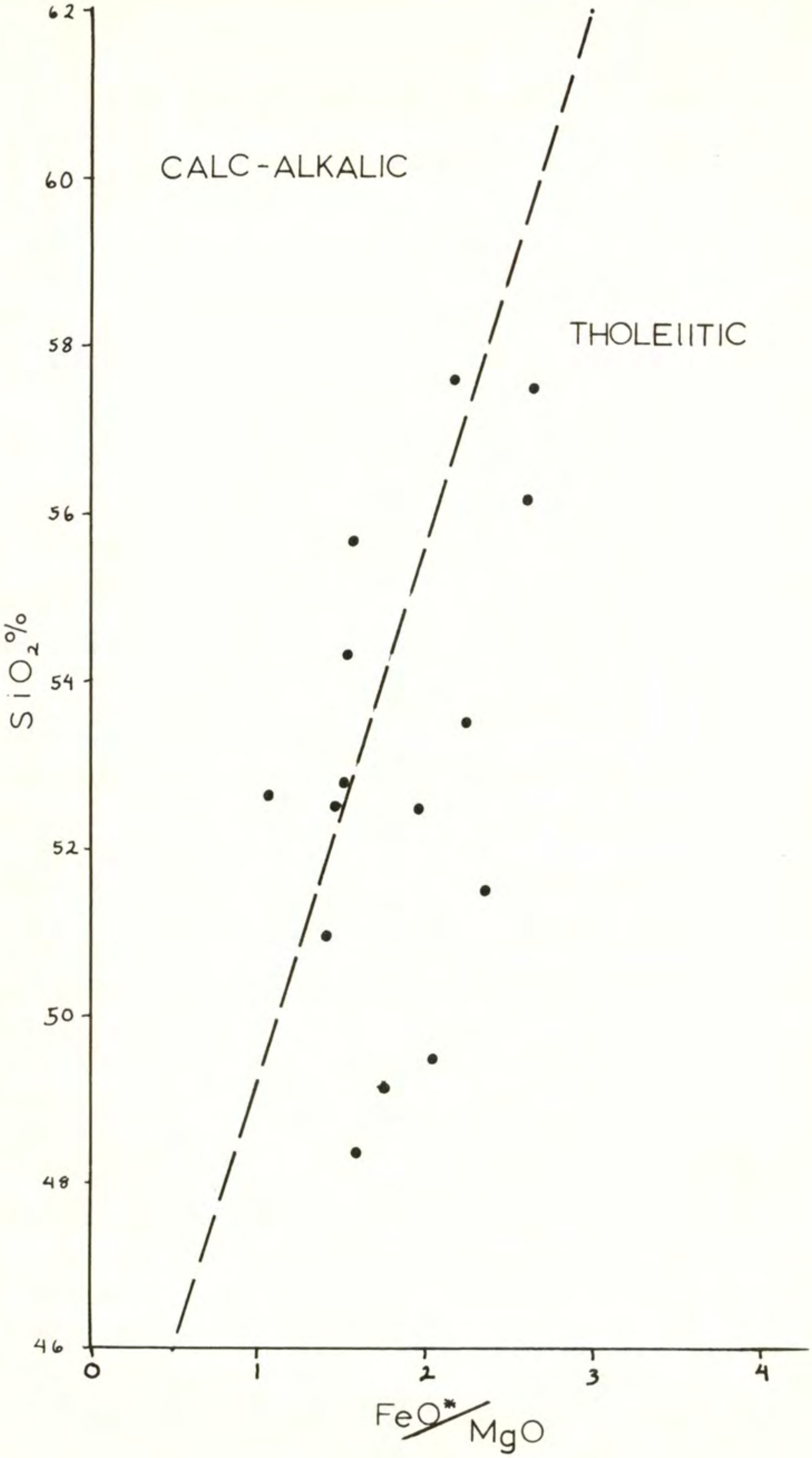


Figure 4c

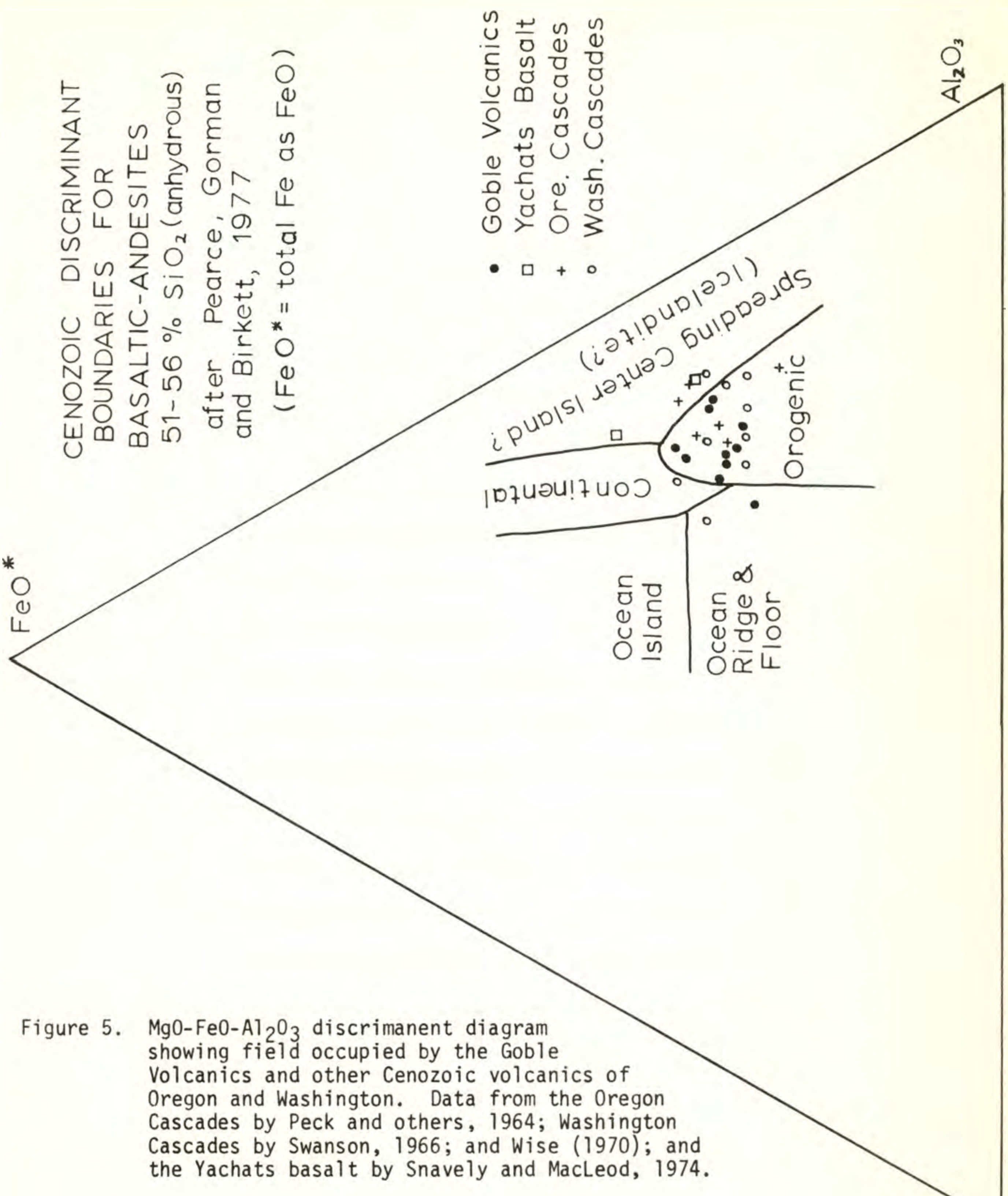


Figure 5. MgO-FeO-Al_2O_3 discrimanent diagram showing field occupied by the Goble Volcanics and other Cenozoic volcanics of Oregon and Washington. Data from the Oregon Cascades by Peck and others, 1964; Washington Cascades by Swanson, 1966; and Wise (1970); and the Yachats basalt by Snavely and MacLeod, 1974.

(Wolfe and McKee, 1972), the Northcraft Formation in the Centralia - Chehalis coal district (Snavely and others, 1958), the Hatchet Mountain Formation (a member of the Goble Volcanic series) in the Toledo - Castle Rock district (Roberts, 1958), and the Tukwila Formation east of Seattle near Renton (Vine, 1962). Snavely and MacLeod (1974) have interpreted these volcanics as centers of late Eocene volcanism that produced low islands along north trending belts on the broad continental shelf in response to horizontal extension and vertical uplift and subsidence (tensional rifting). This model may fit the volcanics in the Coast Range province, since these rocks do have oceanic affinities and chemical compositions suggesting an extensional environment. However, the calc-alkaline rocks of the western belt of the Cascades probably are more related to subduction. Various ideas concerning the origin of these rocks and their tectonic environments are discussed below.

Structures in southwestern Washington consist of broad open folds and minor faults trending northwest-southeast through the region, transverse to the north-south axes of the Coast Range and Cascades. The major folds that run through the study area are the Willapa Hills anticline (Henriksen, 1956) and the Napavine syncline (Roberts, 1958). These folds are 10-20 kilometers across, with limbs that dip up to 10-25°. Faulting has not been recognized by previous workers as playing a major role in the development of this area; however, this lack of recognition may be due to insufficient continuous exposure. Many small faults occur in several outcrops within the study area and a possible very large fault striking north-south along the trend of the Columbia River - Cowlitz River is found several miles east of Longview, Washington.

Structural development has been episodic in the Goble area since at least the Eocene. Three major episodes of diastrophism have been recognized by Henricksen (1956), Snavely and others (1958), and Roberts (1958) in southwestern Washington, and Peck and others (1964) recognized similar episodes in the western Cascade range of Oregon. These episodes occur at the end of the Eocene, in early Miocene (locally also in late Miocene), and in the late Pliocene. These were times of upwarping, volcanism, folding, faulting, and erosion. Each was followed by gentle downwarping and deposition of shallow marine and near-shore sediments.

PALEOMAGNETISM

A total of 392 samples were collected from 42 sites distributed throughout the area of exposure (figure 2). The cores were drilled with portable equipment, oriented with a magnetic compass, and checked with a sun compass wherever possible. Each site consisted of 5 to 17 individually oriented samples drilled at least one meter apart along the exposed length of a single flow. Deep weathering limited sampling to road cuts, quarries, and river exposures. Drilling and orientation procedure and equipment were as described by Doell and Cox (1965).

In the laboratory the cores were cut into standard paleomagnetic specimens and natural remanent magnetization (N.R.M.) measured on a Schonstedt spinner magnetometer model SSM-1A. Secondary components of N.R.M. were removed by alternating field (A-F) demagnetization. The A-F demagnetization level used for each site was based on the minimum angular divergence between two pilot specimens or were chosen as the direction at which their directions stopped changing significantly. For a complete discussion of the alternating field demagnetization technique see McElhinny (1973) or Tarling (1971).

Within-site precision was improved by dropping those samples that, after magnetic cleaning, remained outside the cluster and diverged from the mean by at least twice the angular standard deviation (23 samples were eliminated on this basis). Entire sites were rejected if their 95% circles of confidence exceeded 15 degrees after individual divergent samples were removed (sites 77-19, 77-25, 77-26, and 77-35 were so rejected). Lastly, site 77-20 was rejected because its direction diverged by a large angle from an otherwise tight grouping of directions. This may be due to lack of structural control for this flow. After these exclusions there remained 333 samples and 37 sites.

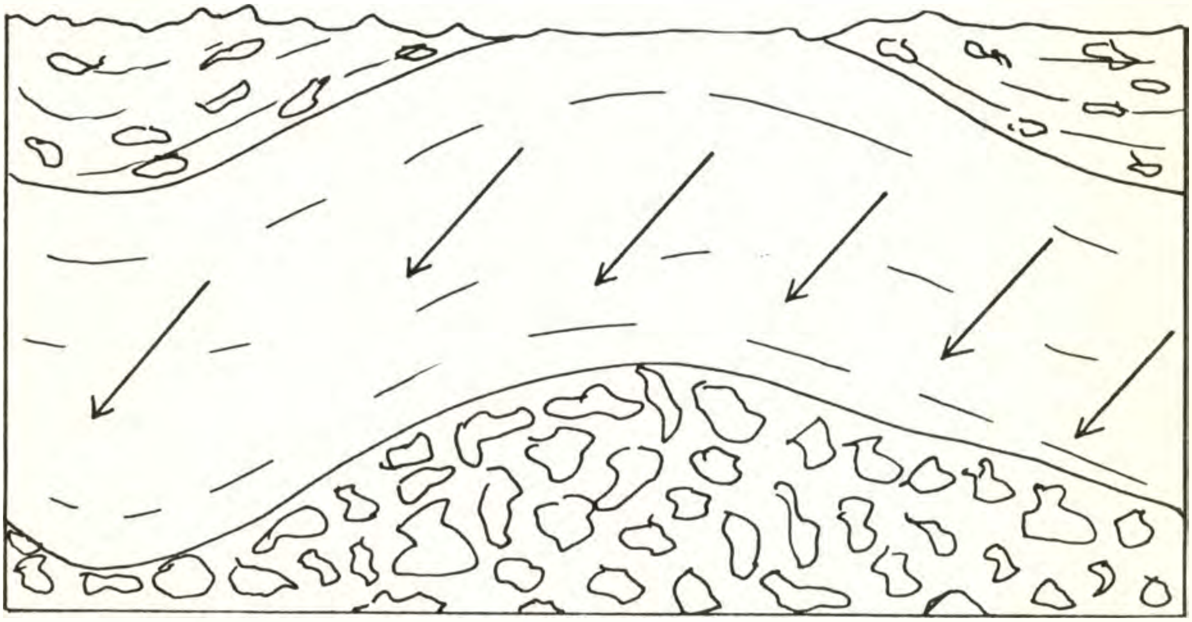


Figure 6. Modified fold test (McElhinny, 1973) illustrating that the directions of magnetization (arrows) from samples collected from different limbs of an apparent fold are the same, which suggest that the basalt flowed over a hill or was remagnetized rather than being folded after magnetization was acquired.

To test whether dips of the flows were original or tectonic, a modified fold test such as described by McElhinny (1973) was used on both individual flows and on the entire area. Fold tests from within individual sites (flows) uniformly failed since magnetic directions from opposite limbs of an apparent fold were the same (see figure 6). There are two explanations for this; either the flow was folded and then remagnetized, or the lava was not folded but merely has flowed over an irregular surface, such as a hill. The former explanation is doubtful as remagnetization would require reheating to high temperatures, and no petrological or magnetic evidence of such reheating exists.

A fold test using the directions from steeply dipping flows (greater than 15°) from the entire area, showed that some tectonic tilting has occurred, because directions tended to converge when tilt corrections were applied (see figure 7). However, when the Goble mean direction was calculated from the site mean directions, kappa (a measure of dispersion, Fisher, 1953) increased by a statistically insignificant amount, from 27.45 for directions not corrected for tilt to 30.54 for directions corrected for tilt. Although these fold tests are not conclusive in a statistical sense, because the amounts of dispersion for the two groups of directions are nearly the same, the large broad anticlines and synclines described earlier that trend northwest through the area tend to support post-magnetization tilting. Based on these observations, tilt corrections were applied to all dipping flows, even though it is suspected that some of the dip is original. "Correcting" for original dip no doubt has tended to add to the scatter, although probably to an insignificant extent. It should be pointed out that the

Figure 7. Fold test illustrating reduction in scatter of the directions of magnetization for 10 flows with dips exceeding 15 degrees. After tilt corrections are applied the directions converge, suggesting that regional folding has occurred. See text for a more complete discussion.

mean directions calculated with and without tilt corrections differ by only 5 degrees and are not significantly different at the 95% confidence level (see figure 8).

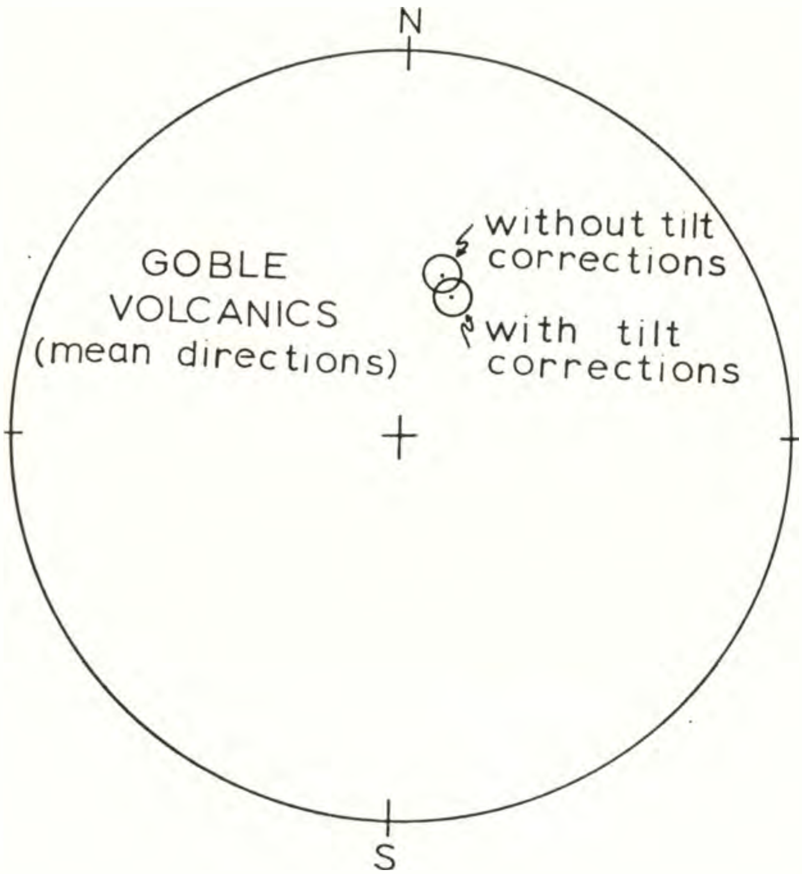


Figure 8. Average magnetic directions with corresponding 95% circles of confidence for the Goble Volcanics with and without the application of tilt corrections. The two directions are statistically indistinguishable at the 95% confidence level.

A plot of all site-mean directions cleaned and corrected for tilt is shown in figure 9. Table I lists the directions calculated for each site along with all other important statistics. Sample directions and stereographic plots for each site can be found in Appendix B.

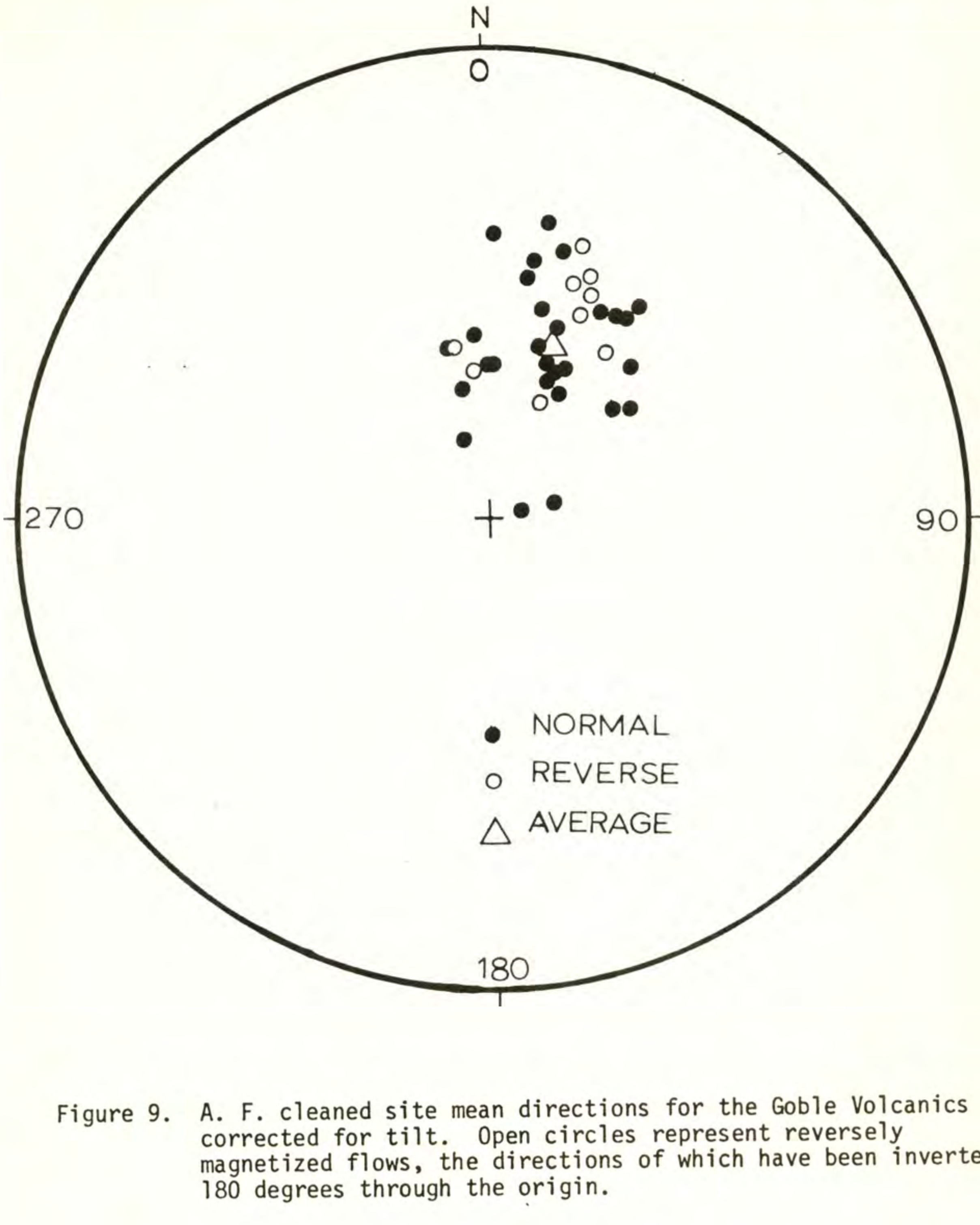


Figure 9. A. F. cleaned site mean directions for the Goble Volcanics corrected for tilt. Open circles represent reversely magnetized flows, the directions of which have been inverted 180 degrees through the origin.

The mean direction for the Goble Volcanics has a declination of 18.5°, and inclination of 57.5° and an α_{95} (circle of confidence) of 4.33°. The error limit on the declination is 8°. The expected middle Tertiary geocentric field direction for southwestern Washington has a declination of 353.5° and an inclination of 61.5°. The error limits on this declination and inclination were approximately 5° and 3° respectively; the 3° error limit on the inclination represents the α_{95} for the expected direction. This direction was calculated using the pole position 84.5°N, 115°E, α_{95} = 3.5°, for stable North America during the middle Tertiary (Beck, unpublished data). Table II summarizes these data.

The difference between the two directions is shown in figure 10. This plot implies that a clockwise rotation of approximately 25° ± 13° has occurred since these rocks were erupted.

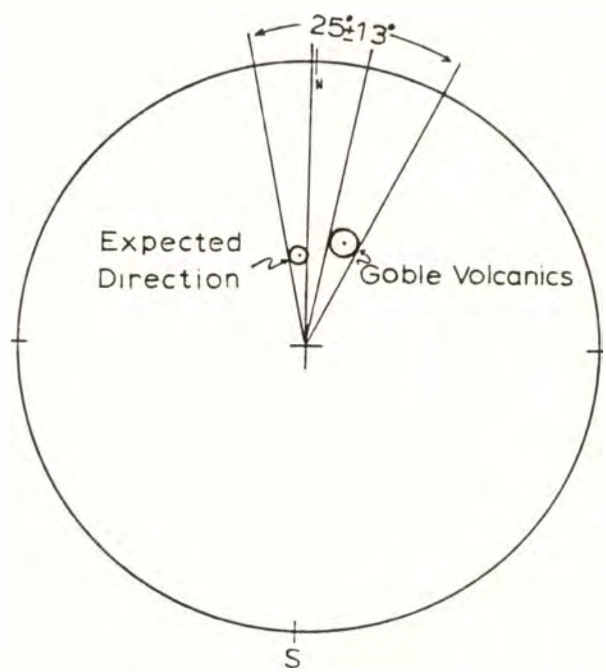


Figure 10. Plot of the direction expected for the Goble Volcanics during the Middle Tertiary and the observed direction. The circles represent the 95% confidence interval and the extended lines represent the error limits on the directions. Thus, 25° ± 13° of rotation can be shown to have occurred since the middle Tertiary.

TABLE I PALEOMAGNETIC RESULTS FOR THE GOBLE VOLCANICS TABULATED AS SITE MEANS

				NRM					CLEANED						V. G. P.		
SITE	LOCALITY	LONG.	LAT.	N	$\overline{D}$	$\overline{I}$	R	α_{95}	N	H (oe)	$\overline{D}$	$\overline{I}$	R	α_{95}	PLONG.	PLAT.	ATTITUDE
77-06	Toutle River	122.58W	46.38N	11	131.68	2.40	8.23677	28.02	11	250	204.02	-51.39	10.77567	6.91	3.18W	66.68N	flat lying
77-07	"	122.63W	46.38N	11	213.50	-38.93	10.73617	7.51	11	500	204.60	-46.90	10.97154	2.44	2.20E	63.43N	"
77-08	"	"	"	14	208.89	-40.89	13.63982	6.71	13	200 &350	202.50	-44.61	12.95924	2.42	8.02E	63.11N	"
77-09	"	"	"	12	210.65	-39.29	11.74099	6.74	11	300	199.19	-46.72	10.90569	4.45	11.38E	66.20N	"
77-10	Coweman River	122.63W	46.15N	6	15.49	56.49	5.89375	9.87	6	200	26.68	61.10	5.93751	7.54	30.47W	70.54N	"
77-11	"	"	"	6	21.53	61.37	5.96879	5.31	6	200	20.42	61.70	5.97029	5.18	27.29W	75.12N	"
77-12	"	122.65W	46.15N	12	33.19	56.03	11.79002	6.05	12	200	43.01	54.18	11.85095	5.09	28.67W	55.80N	"
77-13	"	"	"	9	49.03	58.78	8.96207	6.82	9	200	51.74	59.29	8.89830	5.84	42.51W	52.43N	N 54°E, 4°SE
77-14	Rose Valley	122.85W	46.10N	11	11.04	39.60	10.93262	3.76	11	300	11.26	36.66	10.89582	4.68	33.62E	62.70N	N 80°E, 15°SE
77-15	Carrolls	122.85W	46.07N	11	22.35	51.17	10.81515	6.26	10	200	14.27	52.69	9.95756	3.33	11.71E	73.18N	flat lying
77-16	Kalama River	122.63W	46.05N	17	28.75	45.57	16.62789	5.50	16	150	31.33	48.51	15.82661	3.99	9.46W	60.51N	"
77-17	"	"	"	10	23.27	44.86	9.78583	8.23	10	250	33.69	48.13	9.85302	6.22	11.73W	58.77N	"
77-18	"	122.63W	46.03N	13	8.11	44.09	12.57270	7.96	13	200	48.27	61.78	12.79698	5.44	45.30W	55.97N	N 77°E, 22°SE
77-19	"	"	"	5	47.27	45.14	4.33354	34.03	4	200	59.91	66.29	3.90375	16.72	59.03W	50.39N	N 90°E, 16°S
77-20	"	122.68W	46.03N	7	332.66	46.87	6.76388	12.21	7	100	308.48	76.02	6.04619	5.74	162.26W	56.81N	N 75°W, 32° SW
77-21	"	122.73W	46.02N	8	35.22	57.75	7.92130	5.91	8	200	27.79	65.97	7.90696	6.43	49.69W	71.07N	N 85°E, 5°SE
77-22	"	122.78W	46.03N	10	26.02	48.60	9.83480	6.60	10	150	34.98	44.86	9.94698	3.72	9.70W	59.09N	N 35°E, 11°SE
77-23	Canyon Creek	122.27W	45.93N	7	335.39	60.46	6.25981	22.57	5	150	354.23	64.55	4.87144	13.93	156.79E	85.98N	N 30°W, 20°SW
77-24	"	122.32W	45.95N	7	12.92	54.78	6.84337	9.88	4	200	9.17	47.97	3.96633	9.79	31.49E	71.60N	N 35°W, 16°NE
77-25	"	122.27W	45.93N	8	32.88	49.47	3.10140	81.00	8	200	172.67	26.44	2.75808	90.87	114.08W	29.74S	N 45°W, 20°NE
77-26	"	122.30W	45.94N	10	47.89	46.68	7.71314	28.01	10	200	57.45	48.59	5.15132	51.08	32.82W	42.84N	flat lying
77-27	Amboy	122.48W	45.92N	10	34.43	69.15	9.85797	6.12	9	150	348.27	67.57	8.98267	2.40	178.04W	80.97N	N 45°E, 12°NW
77-28	Chelatchie Pr.	122.42W	45.77N	8	19.51	53.92	7.87412	7.49	8	150	0.69	39.97	7.93993	5.15	55.96E	66.96N	N 55°E, 20°NW
77-29	Merwin Lake	122.45W	45.98N	12	10.17	62.50	10.85482	14.77	9	200	342.42	76.07	8.98094	2.52	145.34W	69.81N	N 60°W, 23°SW
77-30	"	"	"	8	2.10	57.64	7.84305	8.38	8	200	346.56	59.39	7.85201	8.14	121.78E	78.63N	N 30°W, 20°SW
77-31	"	"	"	9	13.25	40.54	8.73662	9.49	9	100	19.59	55.10	8.93372	4.70	4.30W	72.00N	N 90°E, 23°S

TABLE I CONT.

SITE	LOCALITY	LONG.	LAT.	NRM N	NRM $\bar{D}$	NRM $\bar{I}$	NRM R	NRM α_{95}	CLEANED N	CLEANED H (oe)	CLEANED D	CLEANED I	CLEANED R	CLEANED α_{95}	V. P. C. PLONG.	V. P. C. PLAT.	ATTITUDE
77-32	Merwin Lake	122.55W	45.98N	11	353.70	61.27	10.67569	8.35	11	150	347.27	59.20	10.89869	4.62	119.19E	78.95N	N 45°W, 17°SW
77-33	Yale Lake	122.33W	46.03N	16	344.37	55.80	15.88943	3.18	16	150	22.97	64.35	15.93277	2.47	41.09W	74.12N	N 22°E, 25°SE
77-34	"	122.33W	46.05N	10	0.84	42.67	9.85240	6.24	9	100	15.27	41.36	8.92761	4.92	23.57E	64.54N	N 15°E, 20°SE
77-35	E. Fk. Lewis R.	122.27W	45.85N	7	50.30	60.68	3.54471	68.36	7	150	204.69	13.78	3.42635	71.06	151.80W	32.74S	N 40°W, 10°SW
77-36	"	122.33W	45.85N	7	322.81	3.70	1.15127	180.00	7	150	204.50	-62.22	6.88746	8.34	33.45W	72.49N	flat lying
77-37	Coweman River	122.75W	45.17N	13	34.96	49.16	12.67514	6.91	13	150	27.84	49.12	12.90586	3.69	5.76W	63.01N	"
77-38	E. Fk. Lewis R	122.40W	45.85N	9	125.50	22.20	6.07768	38.59	7	150	167.94	-63.74	6.96352	4.72	146.76E	81.56N	N 80°E, 10°SE
77-39	"	122.43W	45.87N	5	247.98	-52.12	4.96356	7.34	5	300	214.82	-55.06	4.98373	4.89	23.38W	61.95N	N 40°E, 12°NW
77-40	"	122.42W	45.86N	9	13.34	72.76	8.64936	11.01	6	50	77.12	84.38	5.94542	7.04	106.34W	47.23N	N 75°E, 16°SE
77-41	Washogal Rv.	122.32W	45.63N	7	341.55	56.67	6.93218	6.45	6	150	10.17	44.53	5.97929	4.32	31.53E	68.93N	N 15°W, 26°NE
77-42	"	122.33W	45.62N	7	356.21	44.35	6.84516	9.82	7	150	358.88	63.73	6.92345	6.86	130.24E	89.18N	N 35°E, 20°SE
77-43	"	"	"	8	357.26	51.16	7.87864	7.35	8	100	15.46	59.14	7.93211	5.48	11.09W	77.33N	N 35°E, 20°SE
77-44	Goble, Ore.	122.88W	46.08N	8	212.71	-66.60	4.08486	60.79	7	300	202.51	-68.63	6.93759	6.19	62.87W	74.19N	N 70°W, 10°SW
77-45	Trojan	122.90W	46.07W	6	19.19	77.41	5.95422	6.44	6	200	79.51	78.94	5.98229	3.99	92.00W	45.79N	N 28°W, 10°SW
77-46	Columbia R. W.	122.88W	45.98N	8	215.21	41.12	4.62443	52.40	8	250	198.88	-39.39	7.82531	8.86	17.81E	61.81N	N 30°W, 10°SW
77-47	"	122.88W	46.02N	9	181.35	-42.78	8.46091	13.82	8	300	165.45	-58.34	7.76356	10.35	119.16E	77.23N	N 60°W, 11°SW

TABLE II MEAN DIRECTIONS AND PALEOPOLE POSITIONS FOR THE GOBLE VOLCANICS AND MIDDLE TERTIARY POLE FOR STABLE N. AMERICA

	LONG.	LAT.	N	$\bar{D}$	$\bar{I}$	R	α_{95}	N	H (oe)	$\bar{D}$	$\bar{I}$	R	α_{95}	PLONG.	PLAT.
Goble Volcanics	122.50W	46.00N	42	20.95	56.82	37.06248	8.15	37	____	18.64	57.61	35.82125	4.33	9.73W	74.20N
Middle Tertiary (stable N. America)	____							____		353.70*	61.70*	____	3.50	115.C0E	84.50N

N - the number of samples in a site
$\bar{D}$ - mean declination, degrees from true north
$\bar{I}$ - mean inclination, degrees, positive downwards
R - length of the resultant vector
α_{95} - radius of the cone of 95 percent level confidence
H - alternating current demagnetizing field in oersteds yielding least dispersion

PLONG - Paleolongitude and paleolatitude of virtual geomagnetic poles (V.P.G.)
AND
PLAT $\bar{D}$ and $\bar{I}$ and latitude and longitude of the site.

ATTITUDE - measured strike and dip on tilted flows.

D* and I* - Expected direction for the latitude 46 N and longitude 122.5W using the pole position 115 E; 84.5 N for stable North America. (for an extended discussion, see text).

DISCUSSION

The rotation observed in the Goble Volcanics is not unusual in the westernmost Cordillera. Many other rock units on the western edge of the continent from Baja California to Alaska also have discordant paleomagnetic directions (Beck, 1976); the amount and kind of discordance found has provided valuable clues to their tectonic histories.

In general there are two ways that paleomagnetic directions are found to be discordant in the Pacific Northwest; either the declinations are rotated, or the inclinations are flattened. In many cases the two are found together. Discordance is judged by reference to the paleomagnetic direction expected at a site, based on the age of the rock studied and the curve of apparent polar wandering for the North American craton. A flattened inclination implies that the microplate has moved northward relative to the continent. This can be described as a rotation along a great circle about an Euler pole 90 degrees away, perpendicular to the plane of the paleomeridian (figure 11a). A rotated declination, however, implies rotation about a vertical axis (Euler pole) through the rotated block (figure 11b). If both declination and inclination are anomalous, the disco-dance may be described as displacement about a general Euler pole that describes the microplates motion as shown by figure 12.

This study shows that discordance in the Goble Volcanics can be explained by rotation relative to North America, about a vertical axis alone. This is also the case for the Coast Range microplate to the west. Paleomagnetic studies by Cox (1957); Clark (1969); Simpson (1977); and Plumley and Beck (1977) have shown that up to 65 degrees of clockwise rotation has occurred since the early Eocene, with the rotation being sensibly continuous through time (see figure 13). Simpson (1977) has

Figure 11. Illustration demonstrating effect of translation or rotation of a continental fragment. (a) Northward translation produces an anomalously flattened inclination. The Euler pole is 90 degrees away and perpendicular to the plane of the paleo-meridian. The arrows show the field of the axial geocentric dipole. (b) Rotation about a vertical axis produces a declination anomaly only. In this case the Euler pole and the axis of rotation are identical.

Figure 12. Illustration demonstrating the effect of rotation and translation of a continental fragment producing both a declination and an inclination anomaly. Unlike figure 11, rotation is about a general Euler pole. As the inclination (I) changes with latitude (λ), its expected inclination can be calculated using the dipole formula: $\tan I = 2 \cot p$. The discordant declination is illustrated by the arrow in the continental fragment before and after rotation.

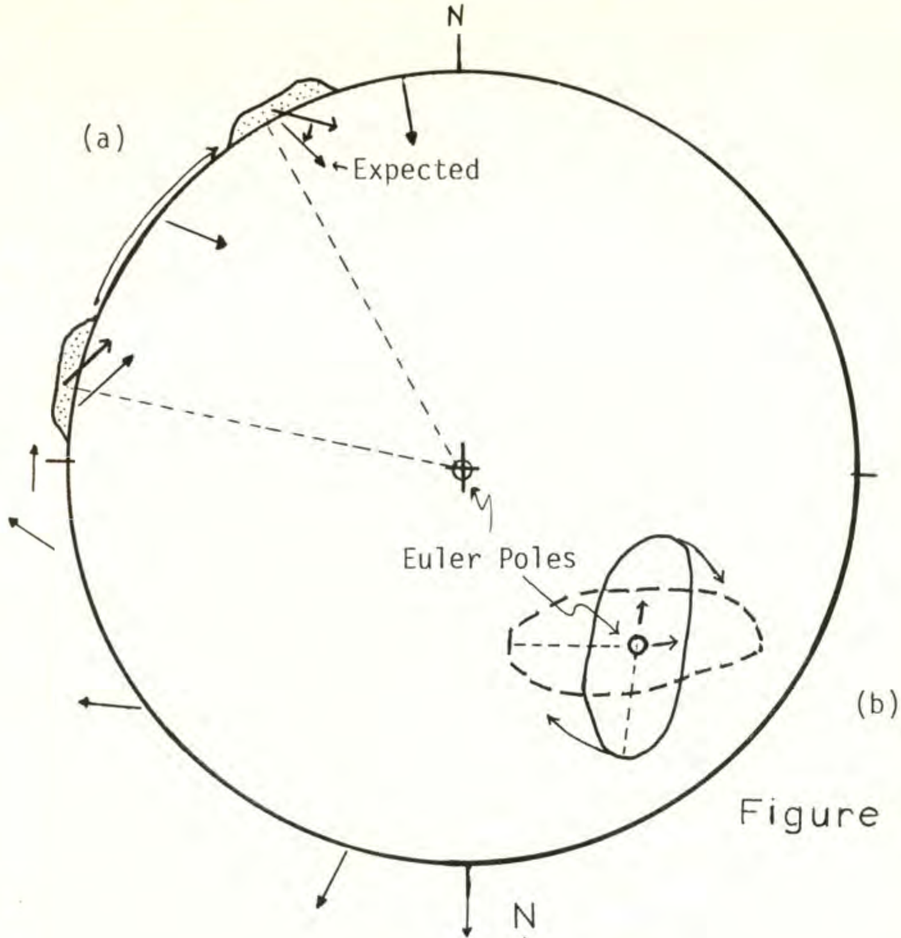


Figure 11

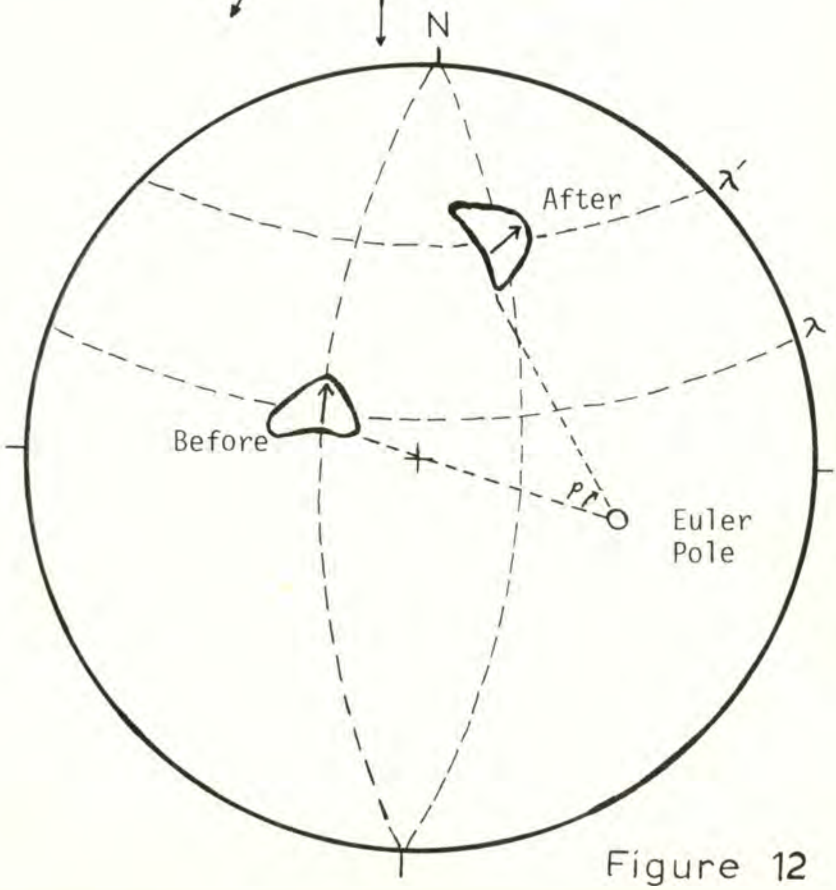


Figure 12

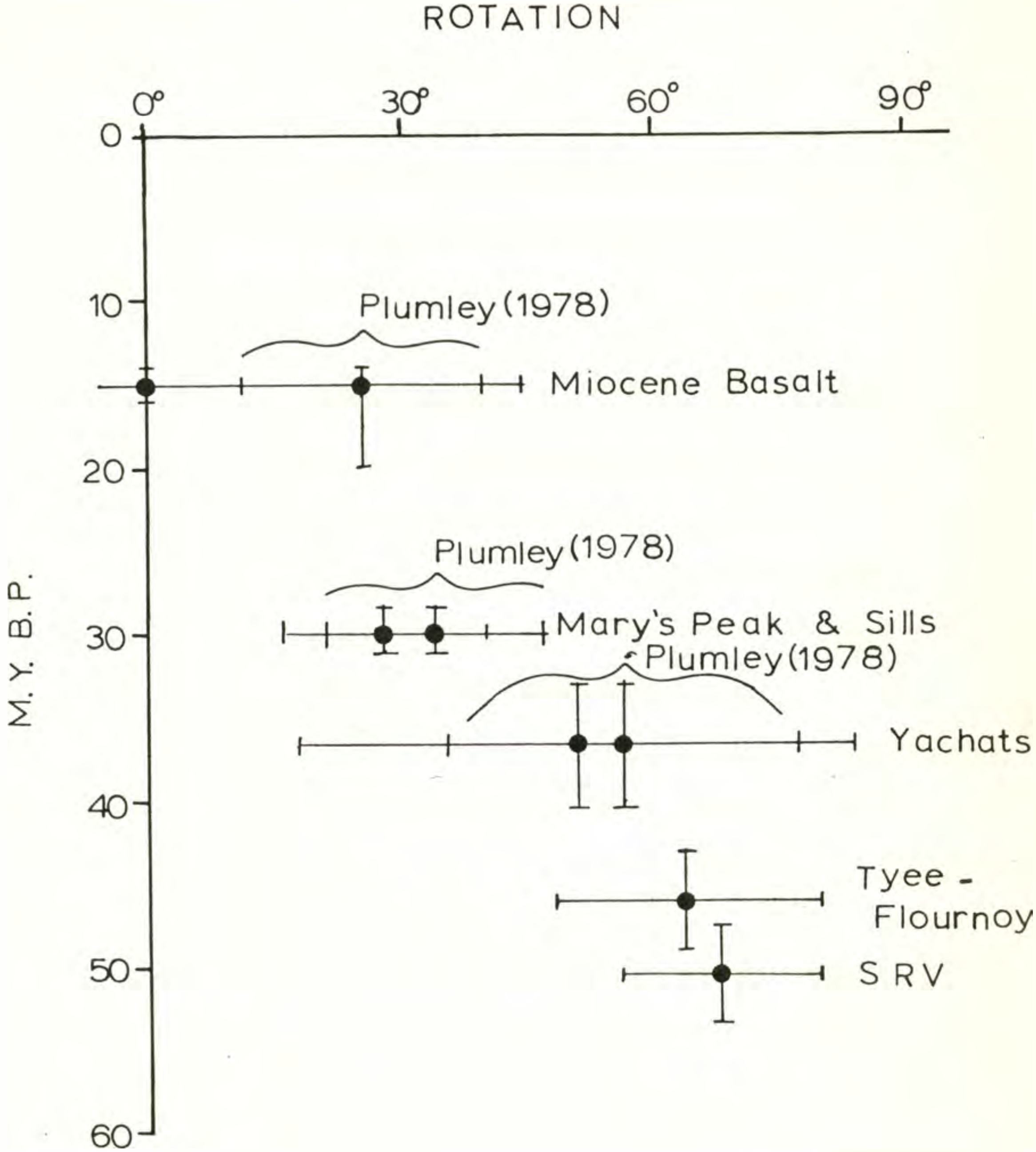


Figure 13. Rotation versus age for rocks in the Oregon Coast Range; data by Simpson (1977) and Plumley (1978). Plumley's results are shown in brackets, all others from Simpson (1977). The diagram suggests that rotation has been nearly continuous since the middle Eocene.

proposed two models to account for this rotation. A brief description of each is given below, along with the problems involved with each.

In Model I Simpson assumes the Oregon Coast Range was a displaced aseismic ridge which formed a coherent block from the Olympics to the Klamath Mountains (figure 14). He also assumes that the coarse clastic sediments interfingering with the Crescent Volcanics in the Olympic Peninsula indicate close proximity to the continental margin, as suggested by Cady (1975). Simpson, therefore, rotates the block back 65 degrees in a counterclockwise direction around a pivot point at its northern end. This places the block parallel to the Olympic-Wallowa lineament and the possible early Eocene northeast-dipping subduction zone suggested by Hamilton (1969), Dickinson (1976) and Snyder and others (1976). It also places the Klamath Mountains 450 km to the east against the Idaho Batholith (figure 14). The mechanism Simpson used to rift the Coast Range and Klamath Mountains seaward toward a newly initiated subduction zone was traction from a mantle diapir, either back-arc spreading, as described by Karig (1971), or from the Yellowstone hotspot. Rotation would begin in late Eocene and the gap left behind the rotating block would be filled with volcanic rocks. The progression of this rotation with time is shown in figure 15.

There are several major problems with this model. First, the upper Eocene Clarno Formation in Oregon has not been rotated significantly (Whitney, 1974; Sherman Gromme, personal communication, quoted by Simpson, 1977, p. 82) and it appears to be in the path of the Coast Range block during its rotation. The Blue Mountains also are in the way and require a prerotation rearrangement, as do the Klamath Mountains. Both of these segments of crystalline rock must be pried loose from a large basement

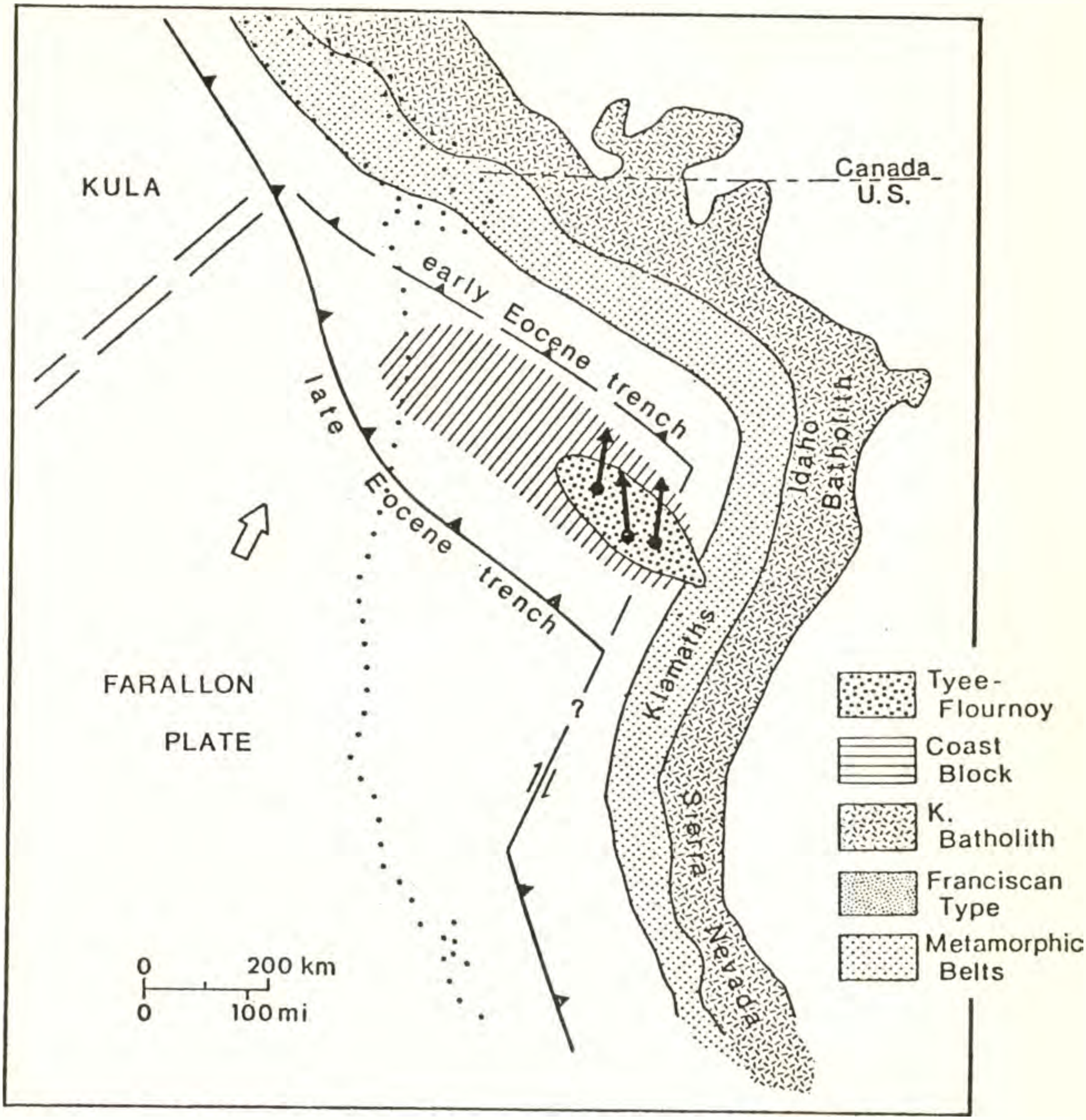
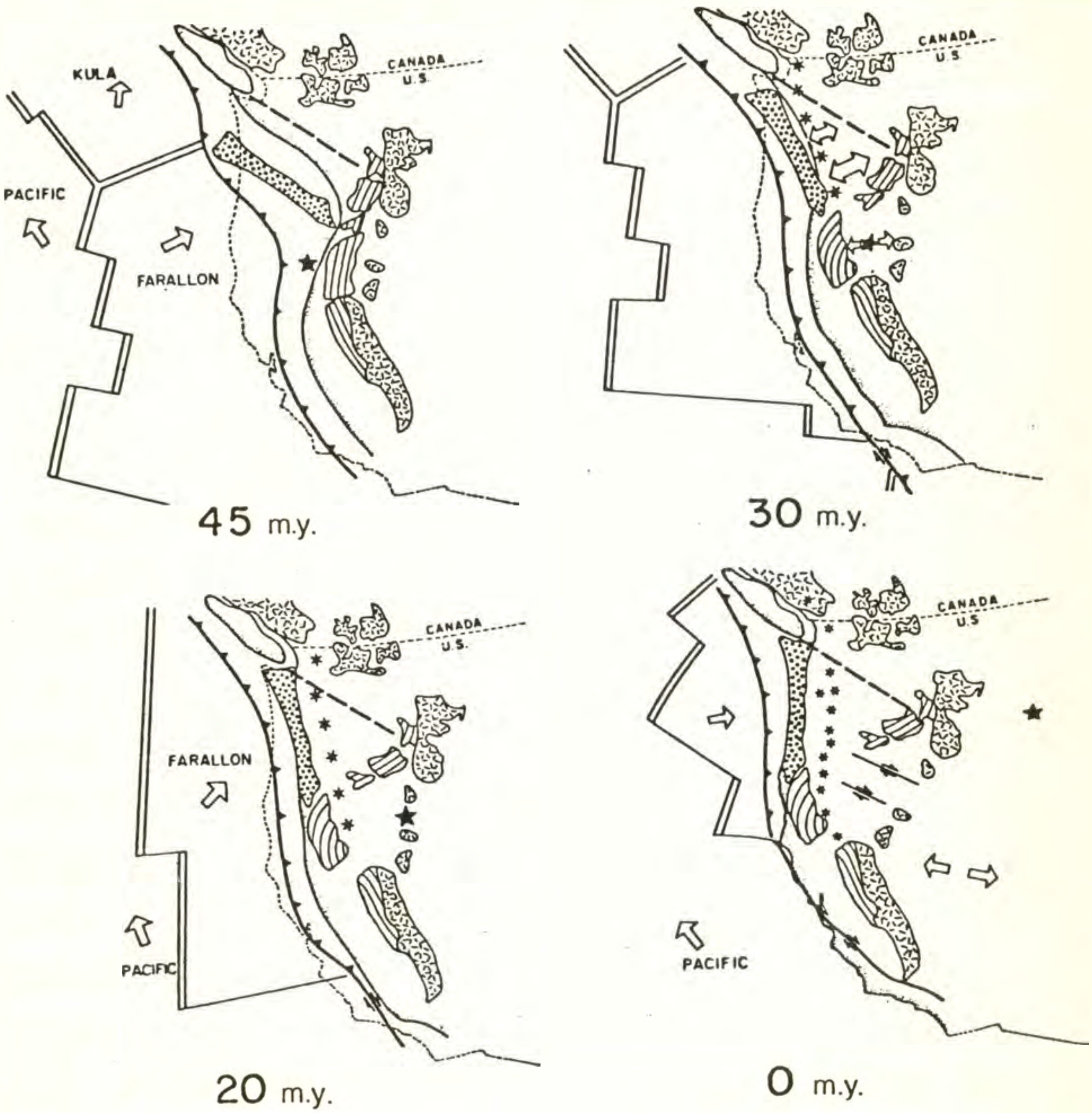


Figure 14. Initial position of the Coast Range block for Simpson's Model I. (from Simpson, 1977, p. 75-76). Pacific Northwest in middle Eocene time, showing the Coast Range Block accreted to the edge of the continent and about to start rotating. Subsequent rifting of metamorphic belts is similar to that envisioned by Hamilton (1969). Dots show present coast.

Figure 15. Simpson's Model I (from Simpson, 1977, p. 79-80) showing proposed evolution of the Pacific Northwest. Circle pattern indicates coastal block underlain by Siletz River Volcanics and equivalent basalts, covered by middle Eocene marine section derived from the erosion of the Klamath Mountains. Lined pattern indicates the Paleozoic and Mesozoic eugeosynclinal rocks which form the metamorphic belts to the west of the Cretaceous batholiths, which are shown by the igneous pattern. Areas covered by pattern have the same size and shape as present day exposure of these units. Small stars represent Cascade volcanoes, large star indicates postulated position of the Yellowstone hotspot. Arrows on oceanic plates indicate approximate directions of motion relative to the North American plate.


KULA
PACIFIC
FARALLON
CANADA
U.S.
45 m.y.
CANADA
U.S.
30 m.y.
FARALLON
PACIFIC
CANADA
U.S.
20 m.y.
CANADA
U.S.
PACIFIC
0 m.y.

complex and moved westward at the same time as the Coast Range. This presents a great problem, but it may not be impossible to resolve. Second, besides Miocene and Pliocene volcanics, there should also be late Eocene and Oligocene rocks erupted in the wake of the rifted Coast Range block. These may be represented in part by volcanic rocks in the Cascades, or they may be buried beneath younger rocks.

A third problem with Simpson's Model I is establishing if and when the separation of the Klamath Mountains from the Sierra Nevada metamorphic belt took place. It has been proposed that the Klamath Mountains were once a continuation of the Sierra Nevada province (Davis, 1969; Jones and Irwin, 1971) and were rifted apart during the Late Mesozoic (Blake and Jones, 1977). However, Simpson's model assumes this separation took place at the time the Coast Range was rotating.

Simpson's second model (Model II) was proposed to alleviate the Clarno, Blue Mountain, and Klamath-Sierra Nevada problems by allowing these to remain stationary. This model assumes that there is a break in the Coast Range block somewhere south of the Olympic Peninsula, and that the block rotated from its southern end (see figure 16). The block is then accreted by subduction of a small plate parallel to the present position of the Puget-Willamette lowland. Following accretion, a new subduction zone would form to the west of the Coast Range block.

The principle problem with Model II is that it lacks an explanation for the existence of a sedimentary basin for deposition of the middle Eocene Tyee and Flourney formations. These sediments, described by Snavely and others (1969) and Lovell (1969), are turbidites apparently derived from detritus of the Klamath Mountains. If the configuration of the Coast Range block shown in figure 16 is correct, it would be

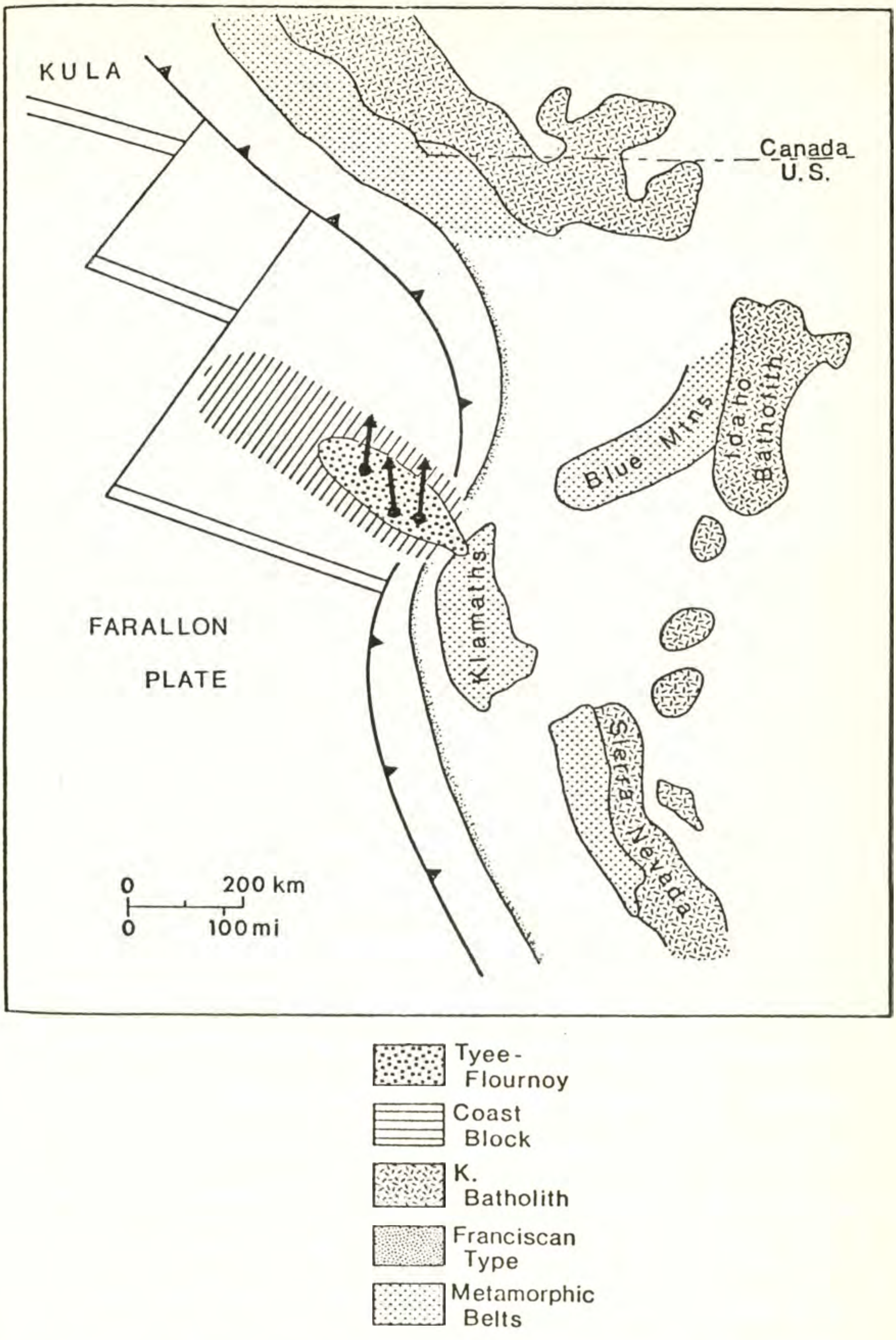


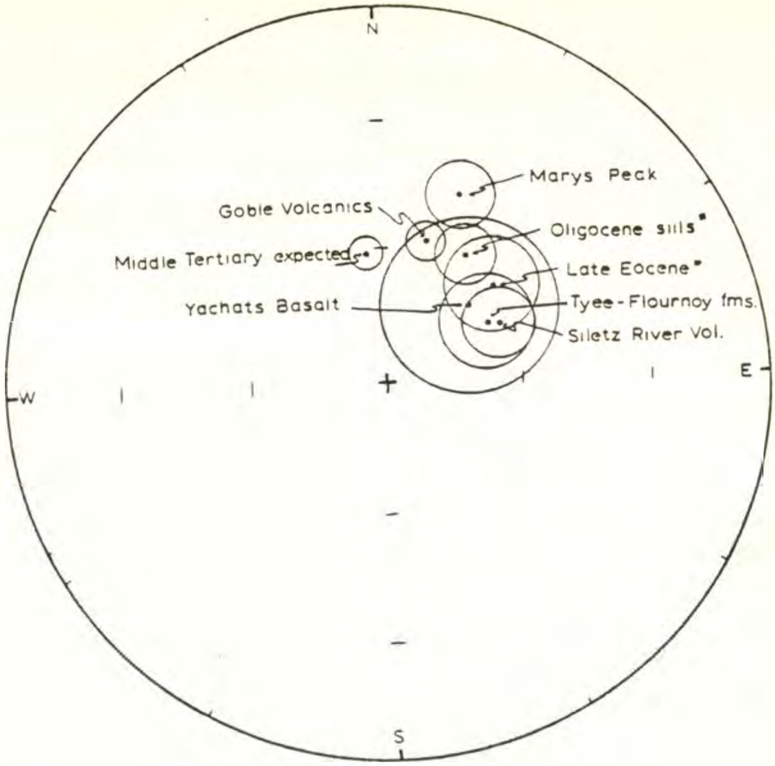
Figure 16. Simpson's Model II (from Simpson, 1977, p. 87-88). Possible configuration of the Pacific Northwest in middle Eocene time.

difficult to explain how the Tyee-Flourney basin formed. Also, the structural deformation that is usually associated with accretion is not present in the Coast Range block. However, this lack may be due to decoupling of the block at its base, a mechanism described by Engebretson and others (1978). Lastly, if the Coast Range extended to below the Olympic Peninsula, then the bulk of the rotation must have occurred prior to the late Eocene, since relatively undeformed Cowlitz sediments overlap the Coast Range and the western Cascades in the Centralia-Chehalis area (Snavely and others, 1958). This makes it difficult to explain the rotation found in the Oligocene sills of the Coast Range.

The results from the Goble Volcanics are significant in that they put constraints on the models described above. When the Goble direction is compared with Simpson's (1977) and Plumley's (1978) results from the Coast Range, there is an apparent difference in the amount of clockwise rotation. This difference is shown in figure 17. From these illustrations it appears that the Goble Volcanics have been rotated less than rocks of similar age in the Coast Range, suggesting that the Goble Volcanics are not part of the Coast Range block. Statistically this cannot be proven because of overlap of 95% circles of confidence for the Goble Volcanics and the Yachats basalt, which is of equivalent age (figure 17). However, the Yachats direction is based on only 8 sites and has a very large error limit (33 degrees). However, other paleomagnetic evidence from the Oregon Coast Range, suggests that the Goble is not part of the Coast Range block. This includes Plumley's data (1978) on late Eocene and Oligocene sills in the Oregon Coast Range. Plumley (1978) has reported 55°±20°

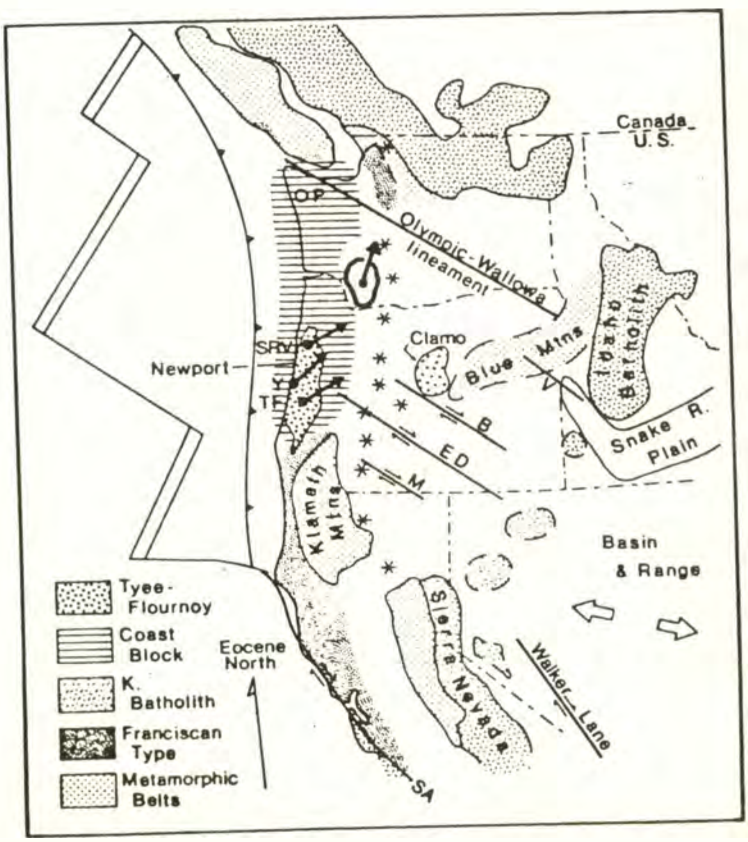
Figure 17. (a) Comparison of the mean directions for the Siletz River Volcanics, Yachats basalt, Tyee and Flourney Formations (Simpson, 1977); Marys Peak Sill (Clark, 1969); and the Oligocene and Eocene mean directions from Plumley (1978), with the mean direction for the Goble Volcanics. The Eocene field direction predicted from the middle Tertiary pole for stable North America (Beck, unpublished data) is also shown. Circles are 95% confidence intervals about the means. See text for discussion.

(b) Generalized geologic and tectonic map modified from Simpson (1977) with the Goble Volcanics and their magnetic direction superimposed on it. SRV = Siletz River Volcanics, Y = Yachats basalt, TF = Tyee and Flourney Formations, OP = Olympic Peninsula. Fault zones and lineaments: V = Vale, B = Brothers, ED = Eugene-Denio, M = McLoughlin, SA = San Andreas.



(a)

* from Plumley (1978)



(b)

of clockwise rotation on the late Eocene rocks and 38°±12° on the Oligocene sills. Also, the preliminary results on the late Eocene Tillamook Volcanics in the northern Oregon Coast Range show more rotation than the Goble Volcanics (Cox and Magill, 1977).

Geophysical and some geochemical data also reinforce the idea that the Goble is not part of the Coast Range block. The Bouguer gravity maps of Oregon (Berg and Thiruvathukal, 1967) and Washington (Bonini and others, 1974) show a steep gradient west of the Goble Volcanic area along the trend of the Puget-Willamette lowland. This gradient probably reflects a sharp break between thick continental crust beneath the Goble Volcanics and Cascades and relatively thin crust beneath the Coast Range. The geochemical data also suggest a distinction between the volcanics in the Coast Range, which are typically oceanic (Snavely and MacLeod, 1974; Snavely and others, 1958; Wolfe and McKee, 1972), and the volcanics in the Cascades, including the Goble Volcanics, which have compositions more typical of a volcanic arc complex (see figure 5).

If the Goble area is not part of the Coast Range block a new problem is encountered for Simpson's Model I. Since the Goble Volcanics were erupted during or prior to the rotation of the Coast Range, it should have as much rotation as the Yachats basalt. This suggests that, like the Clarno Formation, the Goble Volcanics might be "in the way", or must somehow have been dragged behind the Coast Range block without rotating as much as that block did.

An adjustment of Simpson's models that alleviates some of these problems involves removing the constraint that the northern end of the rotated block must extend further north than the Columbia River. This suggestion may be justified by geophysical and geological evidence for the existence of a break in the Coast Range at the Columbia River. This includes: a structural depression along the path of the Columbia River extending to its mouth and also down the Willamette Valley; the Portland fault (Beeson and others, 1975), a large northwest trending right-lateral strike-slip fault, active since at least the late Eocene and a possible continuation of the Brothers fault in central Oregon; Bouguer gravity anomalies northwest of Portland which are offset at least 30 km by the Portland fault, suggesting that the fault continues through the Coast Range; a marked topographic difference in the Coast Range on either side of the Columbia River, the Oregon Coast Range having much more pronounced relief than its counterpart in southwest Washington (Beeson and others, 1975).

Should this break exist the northern end of the rotated Coast Range block might be the Tillamook highland area. If Simpson's Model I applies, the southern end of the Coast Range need not extend as far to the east as Simpson placed it before rotation. This new pre-rotation configuration shown in figure 18a would help eliminate the problem of the Clarno Formation, which would now lie behind the rotating block. Also, the Blue Mountains and Klamath Mountains would not have to be rifted away from their respective metamorphic belts during the time the Coast Range block was rotating. If Simpson's Model II is applied (figure 18b), a break at the latitude of 46°20' would eliminate the necessity for a late Eocene suture, because the oldest rocks that coherently overlap the Coast Range and the western Cascades in northern Oregon are upper Oligocene and Miocene. Thus, rotation of Oligocene rocks also is no impediment. It should be pointed out that until more evidence is found for such a large discontinuity, this break is very speculative. Paleomagnetic studies on the Eocene rocks north of this proposed break should provide valuable information regarding its existence.

How the Goble Volcanics might tie in with either of these models is still largely indeterminable. However, if the Goble Volcanics did rotate as a separate block then there are several other mechanisms that could account for its clockwise rotation without substantial northward translation. These models involve rotation of a roughly equant block, either as part of a series of right-lateral strike-slip faults, or between a subduction zone and a transcurrent fault pair resulting from oblique subduction. These two mechanisms will be called informally the "ball-bearing model" and the "Fitch model", respectively.

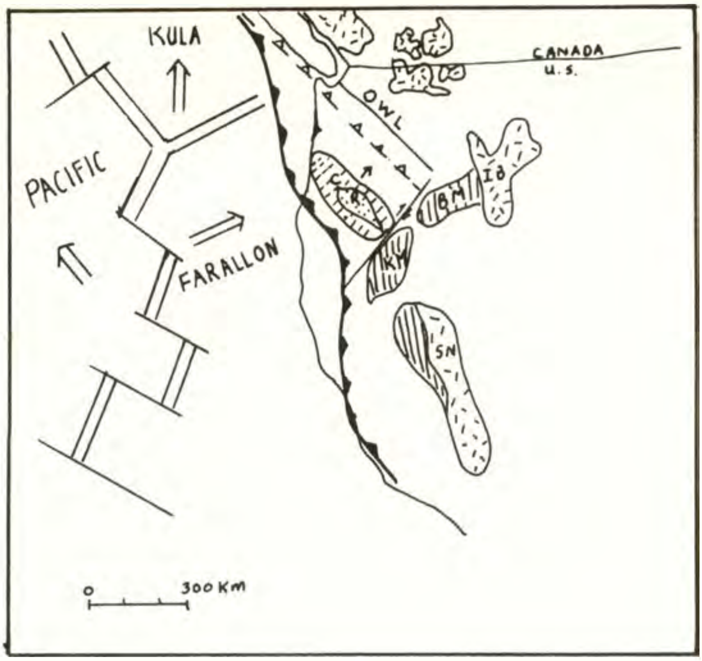
The ball-bearing model for rotation of microplates between zones of right-lateral shear was first proposed by Teissere and Beck (1973) to explain the rotation of the Southern California batholith. Beck (1976) expanded this idea into a possible mechanism to explain clockwise rotations found throughout the westernmost Cordillera. The model, shown in figure 19, describes the motion of continental fragments caught between two plates moving past each other in a right-lateral sense. In this model, simple shear in the ductile lower portion of the lithosphere grades upward into a zone of sub-parallel strike-slip faulting as ductility decreases with falling temperature. Coherent crustal blocks which are caught in such a zone of transform faulting would rotate clockwise and translate northwestward with time like "ball-bearings" (or more accurately, roller-bearings). Each block would be bounded to the northwest and southeast by left-lateral faults or other zones of structural displacement.

Figure 18. (a) Proposed initial position of the Oregon Coast Range block in middle Eocene time assuming it extends only as far as the Tillamook highlands. The block would then pivot from its northern end. The Basin and Range Province has been contracted 180 km at the latitude of the northern Sierra Nevada to restore post-Eocene extension.

(b) Alternative position of the Coast Range Block assuming it rotated from a pivot point at its southern end.

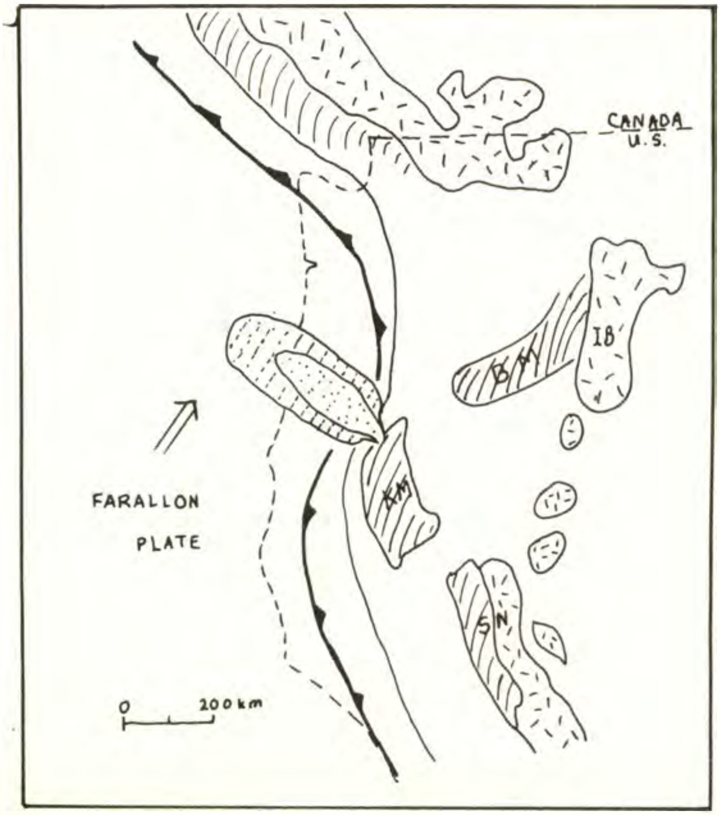
Dashed line pattern indicates the coastal block, dotted interior representing Simpson's study area. Lined pattern represents metamorphic belts west of the Cretaceous batholiths shown in the igneous pattern. KM = Klamath Mountains, BM = Blue Mountains, SN = Sierra Nevada, IB = Idaho Batholith, CR = Coast Range, and OWL = Olympic-Wallowa Lineament.

(a)


KULA
PACIFIC
FARALLON
OWL
IB
BM
KM
SN
CANADA
U.S.
0 300 Km

45 M.Y.B.P.

(b)


CANADA
U.S.
IB
BM
KM
SN
FARALLON
PLATE
0 200 km

Transform faults like the San Andreas, Queen Charlotte, Denali and Tintina faults (figure 1) have played a major role in the evolution of the western Cordillera (Davis, 1977; Jones and others, 1977; Churkin and Eberlein, 1977; Atwater, 1970). Transform faulting and convergence appear to have alternated along the west coast of North America since at least the late Mesozoic, producing magmatic lulls in the rock record, extension within the Basin and Range Province, and pronounced changes in deformational style (Dickinson, 1976; Snyder and others, 1976; Suppe, 1970; Atwater, 1970). Atwater (1970) suggests that at times the Cordillera has behaved as a zone of simple shear across which relative motion between the Pacific and North American plates has been distributed. If this is the case, then it is not difficult to apply the ball-bearing model to account for clockwise rotations found in the westernmost Cordillera.

In southwestern Washington, two sets of faults are possible that could have produced the rotation found in the Goble Volcanics: a north-south set or a northwest-southeast set. If the faults trended northwest-southeast, then possibly the Goble Volcanics were rotated in response to opening up of the Columbia Plateau and Basin and Range Province. Lawrence (1976) has suggested that the Basin and Range Province in Oregon terminates in a series of right-lateral strike-slip fault zones along which total extension and extensional strain rates decrease progressively northward. These faults are supposedly Miocene to Holocene features. However, Beeson and others (1975) have suggested that the Portland fault is the north-westward continuation of the Brothers fault and that it has been active since at least the late Eocene. If extension has occurred within the Basin and Range Province since that time, then the ball-bearing model in conjunction with these faults, or ones of similar orientation, may

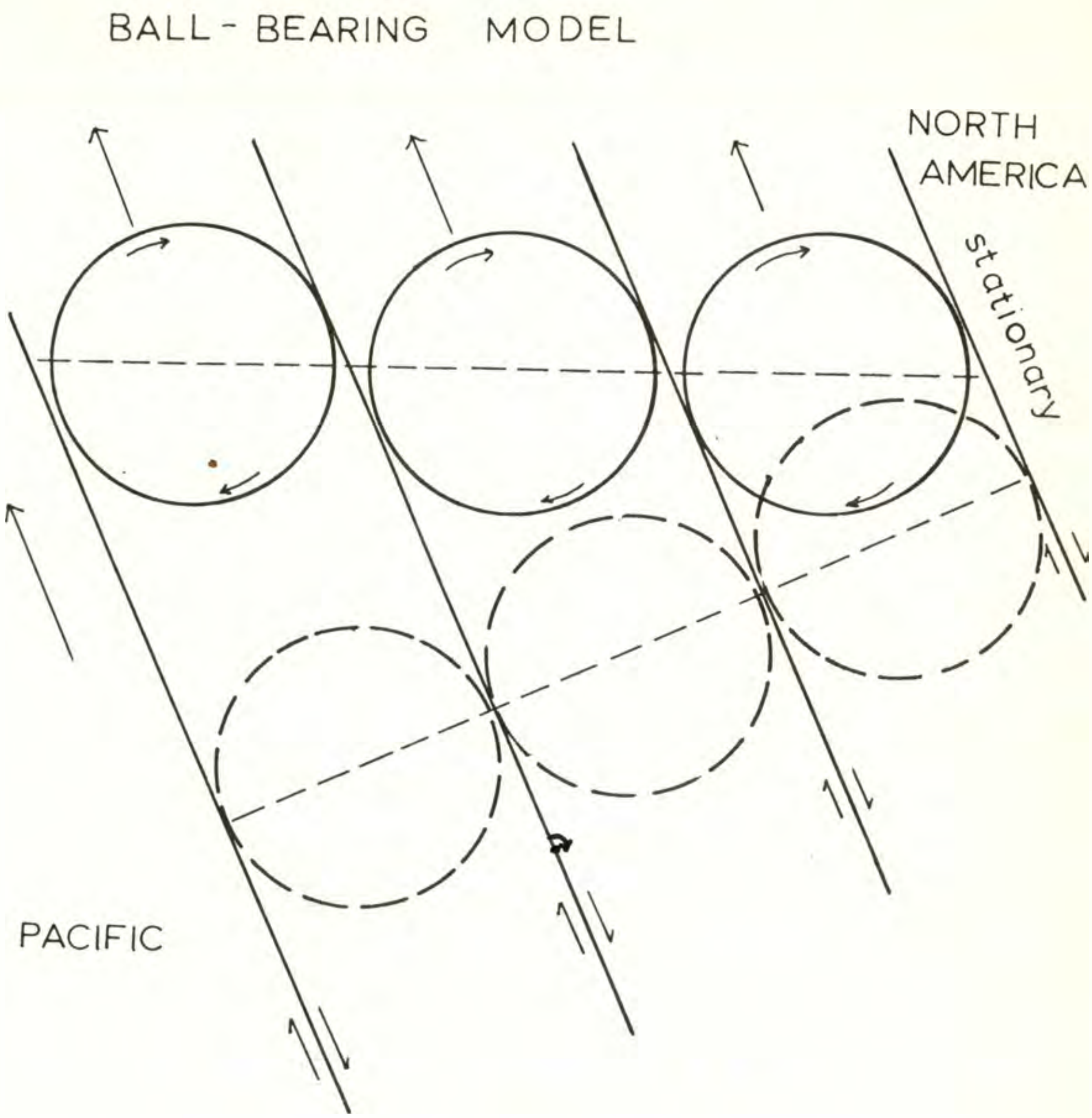


Figure 19. Ball-Bearing method for rotation of continental fragments in a zone of right-lateral shear (Beck, 1976). Circles represent idealized fragments of continental crust which are displaced northwestward and rotated in a clockwise sense. Dashed circles represent initial positions of crustal fragments prior to shearing motion.

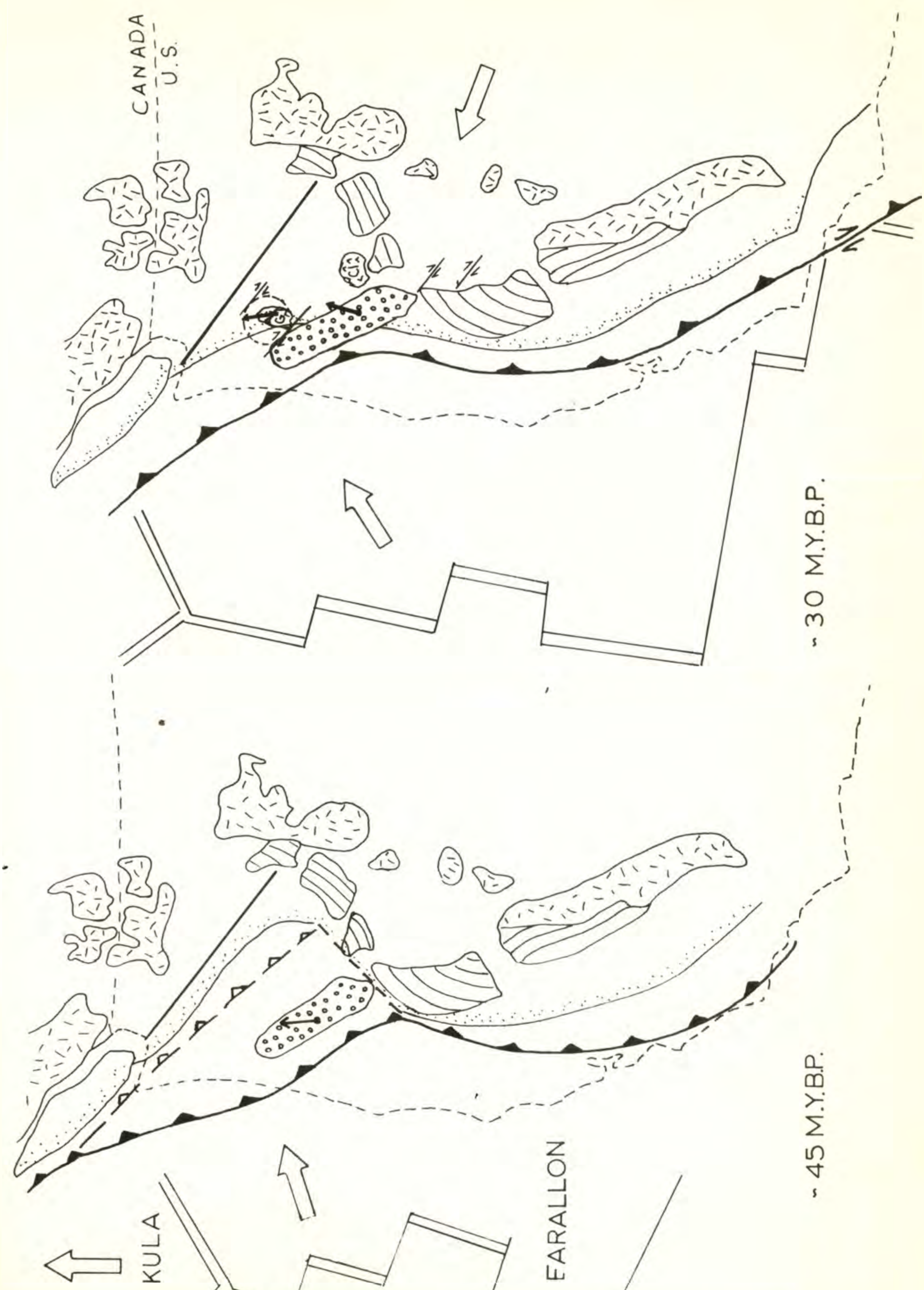
provide the observed rotation. Two possible faults that might bound the Goble block are the Portland fault on the southwest and either a northern continuation of the Vale fault zone or possibly the Olympic-Wallowa lineament to the northeast (figure 1). The corresponding left-lateral faults or other zones of structural displacement that should bound the block on the northwest and southeast, however, do not appear to exist. However, northeast trending gravity anomalies may represent some sort of discontinuity in the subsurface (Wollard and Joesting, 1964). Also, there is a change in the fold pattern from northwest-trending folds in the western belt of the Cascades to northeast trending folds in the eastern Cascades of southern Washington (Hammond and others, 1975, 1977). This change could suggest either a break in structural style or possibly flexure of the folds in response to rotation.

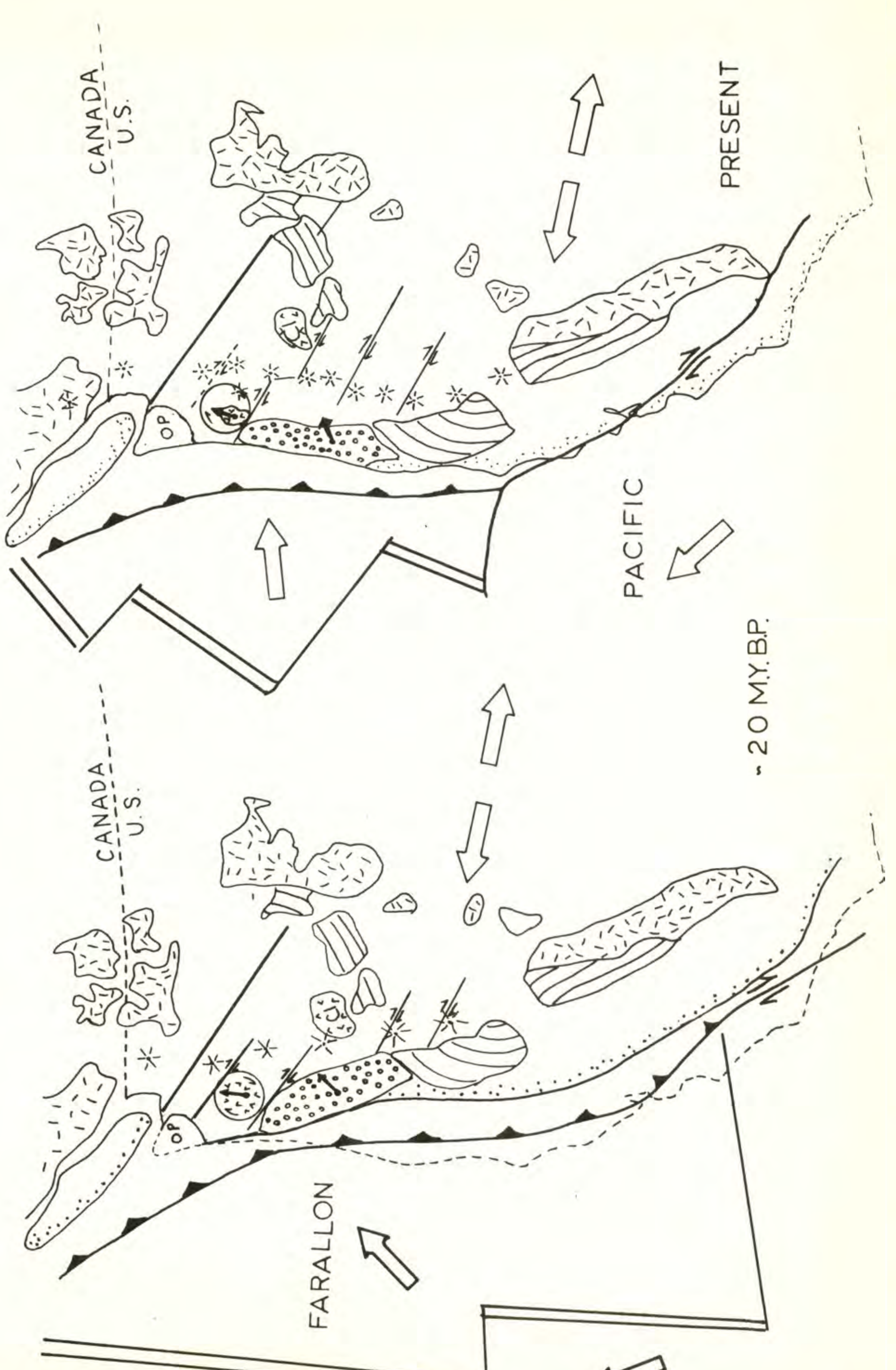
If the ball-bearing model is applicable, rotation had to occur prior to the eruption of the Columbia River basalts, since paleomagnetic results from these rocks within the block do not show rotation (Kienle, 1971; Kienle and others, 1978). A cartoon suggesting the possible evolution of the region is shown in figure 20, in which it is assumed that the Coast Range block extends only as far as the Tillamook highlands. Paraphrasing and modifying a similar discussion by Simpson (1977), the Coast Range block was rafted in during the early Eocene on an oceanic plate that was subducting northeastward under a trench parallel to the Olympic-Wallowa lineament and possibly transforming to the south, separating a very wide zone of arc magmatism to the southeast from a narrow zone of arc magmatism to the north (Snyder and others, 1976; Dickinson, 1976). By middle Eocene the ridge had clogged the subduction zone causing it to jump seaward. From late Eocene through Oligocene the crustal block was rotating in a clockwise sense away from the continent, and subduction-related volcanics such as the Clarno and the Goble Volcanics were being erupted in its wake. Extension behind the arc in the Basin and Range Province, possibly due to back arc spreading (Karig, 1971; Scholz and others, 1971) beginning in late Eocene, produced the set of right-lateral strike-slip faults along which extension occurred, allowing rotation of the coastal block and possibly the Goble block. Since extension was greatest to the southeast, the Coast Range, acting as a coherent elongate block, would tend to pivot around its northern end. To the north basin and range extension decreases, which would produce less rotation of the Goble block between the Olympic-Wallowa lineament and the Portland-Brothers fault than of blocks further south. If the total amount of offset on the Portland fault does not exceed the 40 km of offset found in the late Eocene rocks (Beeson and others, 1975), then the diameter of the Goble block would probably not exceed 100-150 km. Also, since very little right-lateral motion has been reported on the Olympic-Wallowa lineament, the Goble block may tend to pivot from its northern end rather than to roll. Further paleomagnetic work in surrounding areas should provide this needed information.

A major problem which still needs to be resolved in this model is the tectonic environment of the late Eocene volcanics in the Coast Range. These volcanics have been interpreted by Snavely and MacLeod (1974) as products of extensional rifting.

An alternate way to produce ball-bearing rotation is between a set of north-south right-lateral faults during a period which transform

Figure 20. Proposed evolution of the Pacific Northwest accounting for the rotation of the Oregon Coast Range block and Goble block. Circle pattern represents the Coast Range block and the volcanic pattern indicates the late Eocene Goble Volcanics and Clarno Formation. See text for sequence of events.


CANADA
U.S.
~ 30 M.Y.B.P.
KULA
FARALLON
~ 45 M.Y.B.P.


CANADA
U.S.
OP
PRESENT
PACIFIC
~20 M.Y. B.P.
CANADA
U.S.
OP
FARALLON

faulting rather than subduction occurred. A magmatic lull has been recognized in the arc by Vance (1977) between 41-36 m.y., although this is about the time when the Goble Volcanics were erupted. After this time, arc magmatism appears to be continuous until the beginning of Yakima time at about 16 m.y. (Vance, 1977).

Geologic evidence for the existence of this set of north-south faults is scarce. To the east, the younger Cascade volcanics bury all possible evidence except the Straight Creek fault, which was active through the Paleocene and perhaps provided minor movement until the late Oligocene (Vance, 1978, personal communication). On the west side of the Goble block is the sharp gradient in the Bouguer gravity profiles described earlier. However, surface evidence for a fault is unreported. To the north the Devils Mountain fault (Whetten, 1978), a large left-lateral fault, might represent the northern end of a rotated block. However, the Portland fault, which could be a possible southern end of this block, shows right-lateral displacement.

An alternate mechanism for producing rotation of a roughly equant crustal block with little accompanying translation has been developed by Beck and Plumley (personal communication, 1977) after a suggestion by Fitch (1972). Fitch (1972) showed, from examples in the southwest Pacific, that a subduction zone-transcurrent fault pair can result if subduction is oblique. He suggested that a slice of crust between the trench and a transcurrent fault may become decoupled and translate in the direction determined by the sense of oblique subduction. If, instead of translating along the plate margin as a thin, coherent sliver, the crust were broken into equant sized blocks, then these blocks should rotate as well as translate, in much the same way as ball-bearings (see figure 21). This model agrees quite well with estimates of subduction vectors off the western coast for much of the Cenozoic. Plate motions determined by Carlson (1977) and Beck (personal communication, 1978) show that throughout the Tertiary the Farallon plate was subducting obliquely to the northeast at the trench off the coast of Oregon and Washington, assuming the coastline then trended roughly north-south. The angle of oblique subduction and the amount of right-lateral slip can be calculated using motions of the Pacific, Farallon, and North American plates relative to a hot spot framework or to each other by solving the vector equation

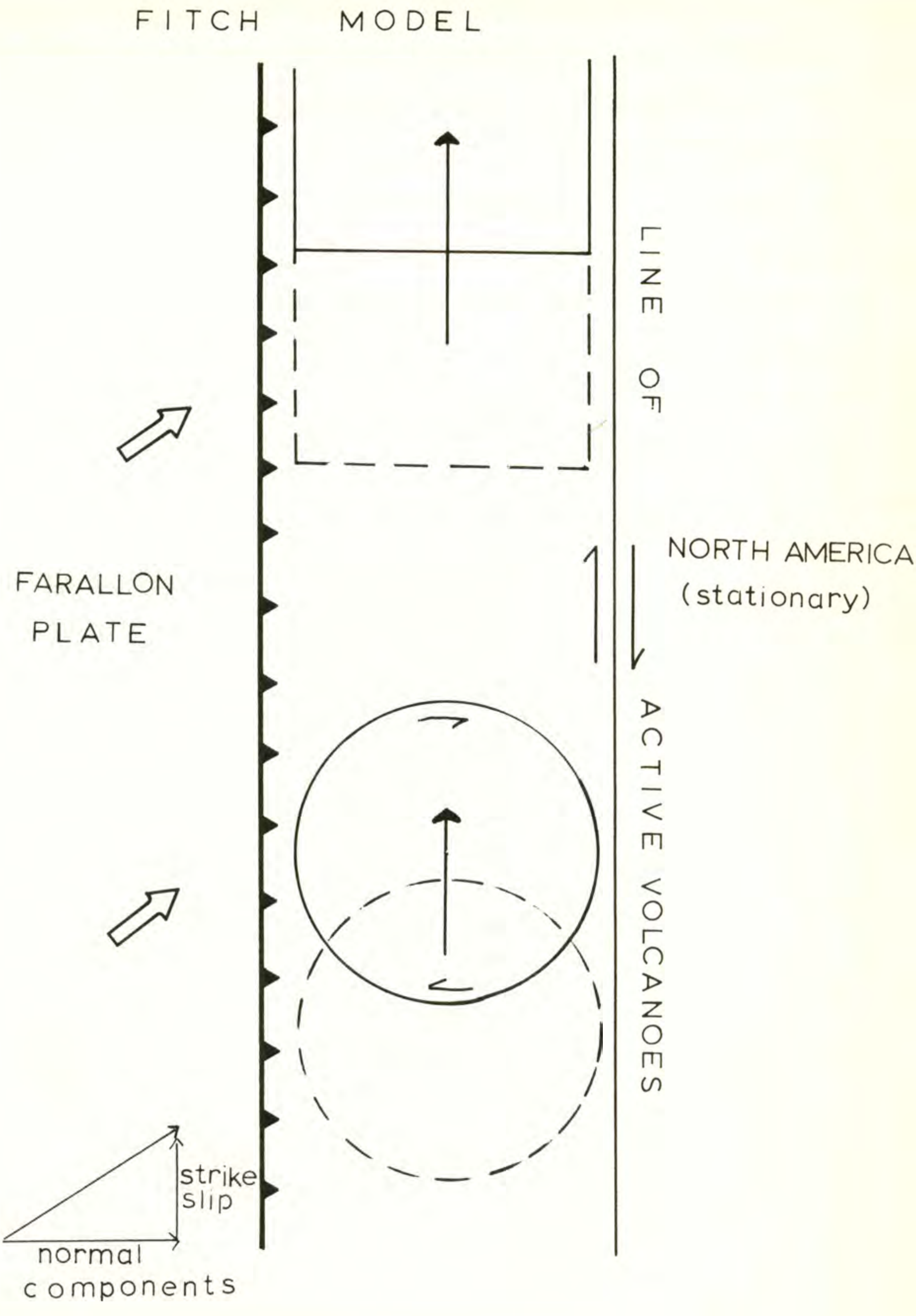
$$F \vec{\omega} NA = P \vec{\omega} HS + HS \vec{\omega} NA + F \vec{\omega} P$$

(F - Farallon, P - Pacific, NA - North America, HS - Hotspot).

The results of these calculations (Beck, unpublished data) for the time span 43 to 32 m.y.b.p. show that the convergence direction between the two plates averaged about N 62 E at a rate of roughly 7 cm/yr. Both direction and rate changed steadily during this time interval, but by an insignificant amount. Assuming a north-south continental margin, the strike-slip (right-lateral) component of convergence throughout the time interval amounted to about 3.5 cm/yr. Thus, a large component of right-lateral strike-slip faulting is possible and might be used to explain the clockwise rotation of the Goble Volcanics.

The essential elements that this model requires is a fault to the east of the Goble Volcanics, possibly along a lone of active volcanoes (a zone of natural weakness). No right-lateral fault zone is reported to exist to the east; however, the evidence may be buried beneath

Figure 21. The Fitch Model, to account for rotation of a crustal block between the trench and a right-lateral strike-slip fault resulting from oblique subduction. An elongate block would translate northward only. If the block were roughly equant it should rotate clockwise and also translate northward with time. The zone of strike-slip faulting may follow the line of active volcanoes (modified from Plumley, Engebretson and Beck, 1977, personal communication).


FITCH MODEL
LINE OF ACTIVE VOLCANOES
NORTH AMERICA
(stationary)
FARALLON
PLATE
strike
slip
normal
components

younger volcanics of the Cascades. This model also requires faults striking nearly east-west to produce a large roughly equant block rather than a slice. The block would extend from the strike-slip fault to the trench, a distance of 75 to 200 km depending on the location of the trench. The Leech River (Muller, 1977) or Devils Mountain faults (Whetten, 1978) could be the northern east-west boundary. To the south the Portland fault could represent the possible southern break, but again motion on this fault appears to be in the wrong sense to that needed for this proposed model. However, the possibility for the existence of a left-lateral fault not exposed now should not be ruled out.

CONCLUSIONS

1) The Goble Volcanics have a mean direction of remanent magnetization of $\overline{D} = 18.5°$, $\overline{I} = 57.5°$ with an $\alpha_{95} = 4.3°$

2) When the Goble direction is compared to an expected direction based on the paleomagnetic pole for the middle Tertiary of interior North America, $\overline{D} = 353.5°$ and $\overline{I} = 61.5°$, approximately 25° ± 13° of clockwise discordance is observed. This suggests that the Goble Volcanics have been rotated 25° clockwise, with little or no north-south displacement, since the late Eocene.

3) The Goble Volcanics probably do not form part of the rotated Coast Range block of Cox (1957), Simpson (1977) and Plumley (1978), where up to 65 degrees of clockwise rotation has occurred since the middle Eocene. However, this cannot be shown conclusively until more paleomagnetic results on late Eocene volcanics in the Oregon Coast Range can reduce the error limits on rotation for this period. Geochemical contrasts between the Goble and Coast Range area also are observed. The Goble Volcanics probably are arc-tholeiites or calc-alkaline rocks, and may represent initial magmatism of the Cascade arc, whereas the basalts of similar age in the Coast Range are related to extensional rifting in an oceanic environment. Lastly, the Goble Volcanics are separated from the Coast Range by the Puget-Willamette lowland, a marked discontinuity suggested by a steep gravity gradient between anomalously thin crust beneath the Coast Range and normal crust beneath the Cascades.

4) Much more work needs to be done before an acceptable model for the tectonic evolution of the Oregon-Washington Coast Range and the early

Cascade Arc can be formulated. In this thesis two models proposed by Simpson (1977) for the rotation of the Oregon Coast Range are examined and shown to have several major problems. Two suggestions for rotation of roughly equant blocks also are discussed. These are: (1) the "ball-bearing model" that produces displacement in a clockwise sense between right-lateral faults in a large continental margin shear zone; (2) the "Fitch model" that involves rotation, also in a clockwise sense, between a subduction zone and a transcurrent fault pair formed in response to oblique subduction. Finally, a preferred but highly tentative model for the Tertiary tectonics of both the Coast Range and Goble block is described. This model is summarized below.

The preferred model assumes that there is a break in the Coast Range block near the Columbia River. This break may be recognized by offsets in the gravity anomalies produced by the Portland fault. This model is similar to Simpson's Model I in that it involves rotation of an elongate block seaward around a northern pivot point (in this case, however, the Tillamook highland). Because the rotated block is shorter than in Simpson's model, certain difficulties with Simpson's model are avoided, the Clarno Formation would no longer be in the way, and the Klamath and Blue Mountains would no longer require extensive rifting and displacement during the late Eocene. The Goble Volcanics in this model rotate independently, ball-bearing fashion, between two northwest-southeast trending fault zones, perhaps the Portland fault and, less certainly, the Olympic-Wallowa lineament.

5) Further work that is essential to help unravel the tectonic evolution of the western Cordillera in Oregon and Washington includes paleo-

magnetic studied, structural geology and more age date control. Specifically, paleomagnetic studies of the Coast Range in Washington are crucial for justifying the existence of a break in the coastal block. Paleomagnetic studies on late Eocene to early Miocene rocks should prove useful to test whether rotation was continuous with time in the Washington Cascades and whether the Cascades in Oregon rotated along with the Oregon Coast Range. Also, structural geology work is critically needed to determine the structures in the region and the orientation of major stress patterns. Finally, more age control is needed to determine igneous events and allow for more accurate correlations between various provinces.

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APPENDIX A.

Geochemical analyses of the Goble Volcanics.

Samples were chosen randomly from 15 paleomagnetic sites encompassing the entire area. In thin section, most of these samples were relatively unaltered. Whole-rock chemical analyses were obtained by x-ray fluorescence methods on an EDAX - EXAM, Model 704, energy dispersive spectrophotometer. The following elements were determined: Si, Al, Total Fe, Mg, Ca, K, Na, Ti, and Mn.

Accuracy of the technique was checked with atomic absorption and is considered to be within ±5 percent of the amount present for all elements except Si and Ti which were not determined on the atomic absorption unit.

CHEMICAL COMPOSITIONS OF THE GOBLE VOLCANICS

Oxide	CBa	CBb	77-06	77-10	77-11	77-14	77-20	77-23
SiO_2	55.7	52.68	57.61	52.54	49.49	57.52	56.17	51.53
Al_2O_3	16.69	15.56	16.37	17.4	14.93	18.77	16.35	16.9
FeO^*	7.73	7.57	7.43	8.90	11.12	7.87	8.32	10.67
MgO	4.86	7.17	3.38	5.8	5.46	2.98	3.53	4.97
Na_2O	2.91	2.61	3.03	2.7	2.81	3.05	3.01	2.81
K_2O	0.53	0.41	1.05	0.5	1.09	0.7	1.1	0.41
CaO	8.65	9.25	7.34	11.34	5.88	9.15	6.55	9.97
TiO_2	1.98	1.39	1.68	2.42	2.91	2.18	2.34	2.61
MnO	0.12	0.06	0.03	0.14	5.66	0.11	0.07	0.14
Total	99.17	96.70	97.92	101.84	99.35	102.33	97.44	100.01

FeO^* - total iron recalculated as FeO.

Location of samples		Rock Type	Texture	Phenocrysts	Alteration
CBa	Trojan	basaltic andesite	porphyritic	augite, plagioclase	slight
CBb	Kalama River	andesitic basalt	porphyritic	augite, plagioclase	some alter. of plag.
77-06	Toutle River	basaltic andesite	cumulophyric	augite, plagioclase	slight
77-10	Coweman River	andesitic basalt	porphyritic	plagioclase	some alter. of plag.
77-11	Coweman River	basalt	porphyritic	plagioclase	moderate alter. of plag.
77-14	Rose Valley	basaltic andesite	porphyritic	augite, plagioclase	slight
77-20	Kalama River	basaltic andesite	cumulophyric	olivine, plagioclase	slight
77-23	Canyon Creek	basalt	trachytic	olivine, plagioclase	some alter. of ground-mass

CHEMICAL COMPOSITIONS OF THE GOBLE VOLCANICS (cont.)

Oxide	77-25	77-30	77-34	77-35	77-41	77-44	77-46	Average
SiO_2	50.98	52.25	48.36	49.17	53.16	52.78	54.33	52.98
Al_2O_3	16.93	16.57	15.45	16.26	18.67	16.07	16.48	16.63
FeO^*	9.37	10.35	11.17	11.02	9.80	8.70	8.29	9.23
MgO	6.67	5.26	7.08	6.29	4.29	5.7	5.34	5.25
Na_2O	2.58	2.86	2.49	2.6	2.94	2.64	2.86	2.79
K_2O	0.28	0.63	0.23	0.43	0.31	0.35	0.54	0.57
CaO	12.22	10.33	11.18	10.94	12.14	11.1	9.41	9.70
TiO_2	1.78	2.97	2.52	2.83	1.92	1.88	1.79	2.21
MnO	0.16	0.2	0.13	0.2	0.12	0.13	0.13	0.12 (0.49)
Total	100.97	101.42	98.61	99.74	103.75	99.35	99.17	98.48

FeO^* - total iron reculculated as FeO.

Location of samples		Rock Type	Texture	Phenocrysts	Alteration
77-25	Canyon Creek	basalt	trachytic	plagioclase	slight
77-30	Merwin Lake	basaltic andesite	porphyritic	augite, plagioclase	slight
77-34	Yale Lake	basalt	porphyritic	plagioclase, augite	slight
77-35	E. Fk. Lewis Riv.	basalt	porphyritic	plagioclase, augite	some alter. of plag.
77-41	Washogal Riv.	basaltic andesite	porphyritic	plagioclase	slight
77-44	Goble, Ore.	basaltic andesite	porphyritic	plagioclase, augite	slight
77-46	Columbia Riv. W	basaltic andesite	porphyritic	plagioclase, augite	some alter. of plag.

APPENDIX B

PALEOMAGNETIC RESULTS FOR EACH SAMPLING LOCATION

FISHER ON SAMPLE DIRECTIONS

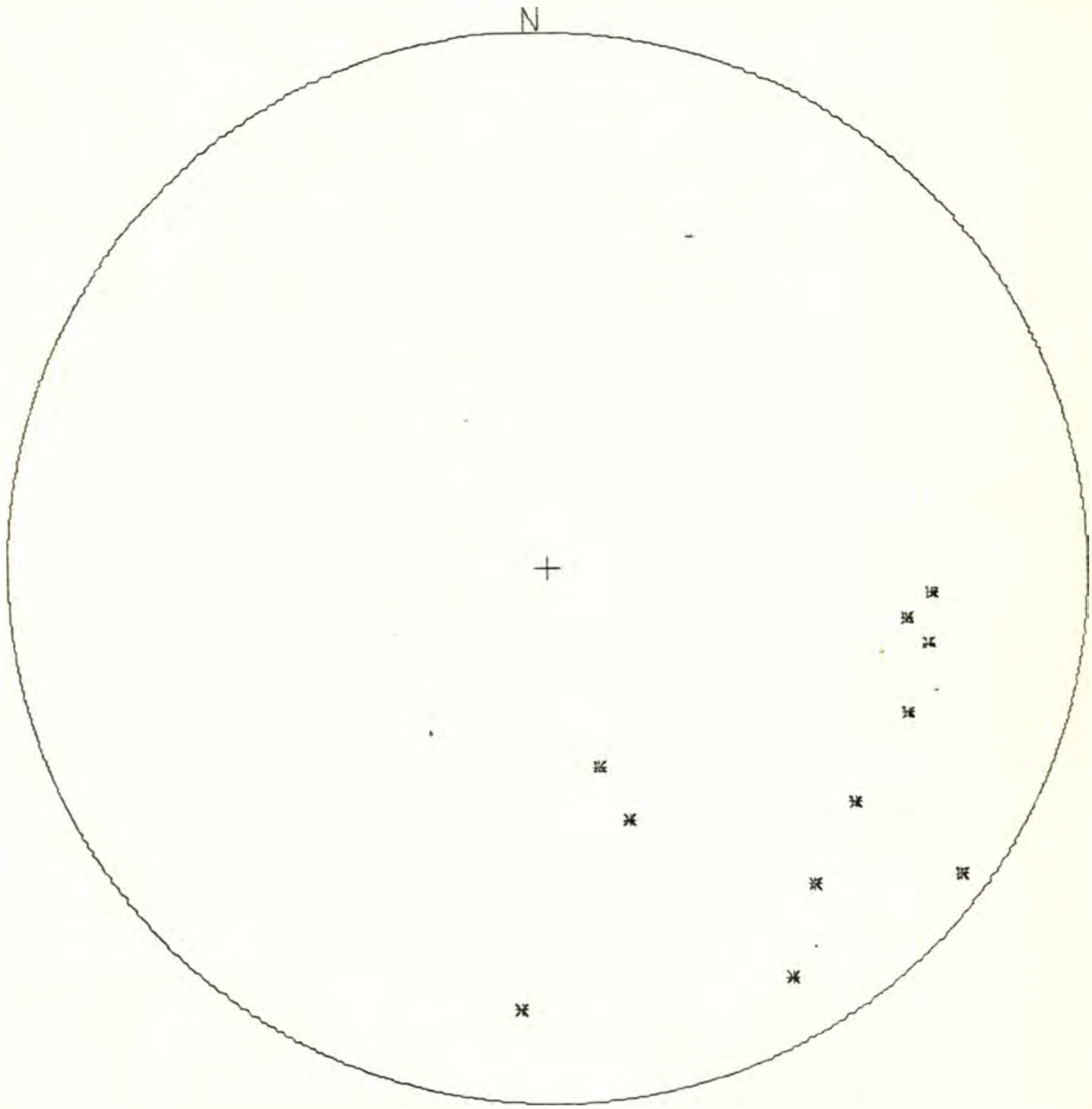
77-06B, NRM TOUTLE RIVER 1

SAMPLE NUMBER	DECLINATION	INCLINATION
032	162.86	-49.01
033	112.49	29.09
034	127.31	-5.38
035	101.73	28.99
036	94.13	29.71
037	166.17	-58.54
038	150.11	-12.28
039	128.04	-29.33
040	140.88	24.37
041	98.53	33.53
042	184.00	18.54

R= 8.23677 DECLINATION= 131.68 INCLINATION= 2.40

ALPHA= 28.02 DELTA= 41.51 KAPPA= 3.62

SITE LATITUDE= 46.38 SITE LONGITUDE=-122.58



77-06B, NRM TOUTLE RIVER 1

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-06B, 250 OE

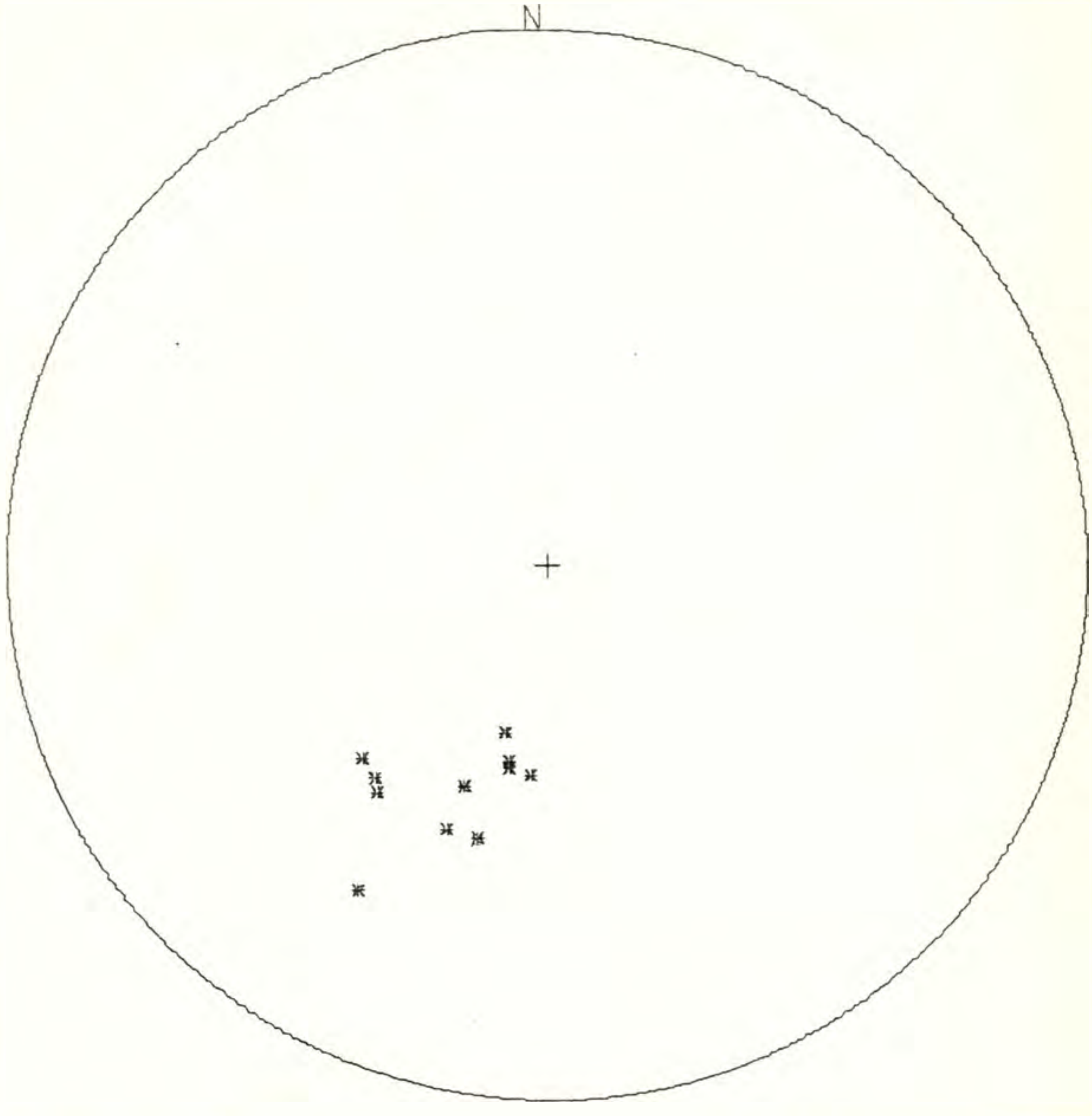
SAMPLE NUMBER	DECLINATION	INCLINATION
032	201.05	-53.55
033	210.43	-30.51
034	184.94	-57.59
035	194.99	-46.17
036	191.15	-58.37
037	191.55	-59.35
038	216.90	-46.19
039	219.19	-47.80
040	194.59	-63.54
041	223.75	-48.74
042	201.13	-46.20

R= 10.77567 DECLINATION= 204.02 INCLINATION= -51.39

ALPHA= 6.91 DELTA= 11.59 KAPPA= 44.58

PLAT= 66.68 PLONG= -3.18 DELP = 6.38

DECLM= -9.39 STLAT= 46.38 STLONG=-122.58



77-06B, 250 0E

FISHER ON SAMPLE DIRECTIONS

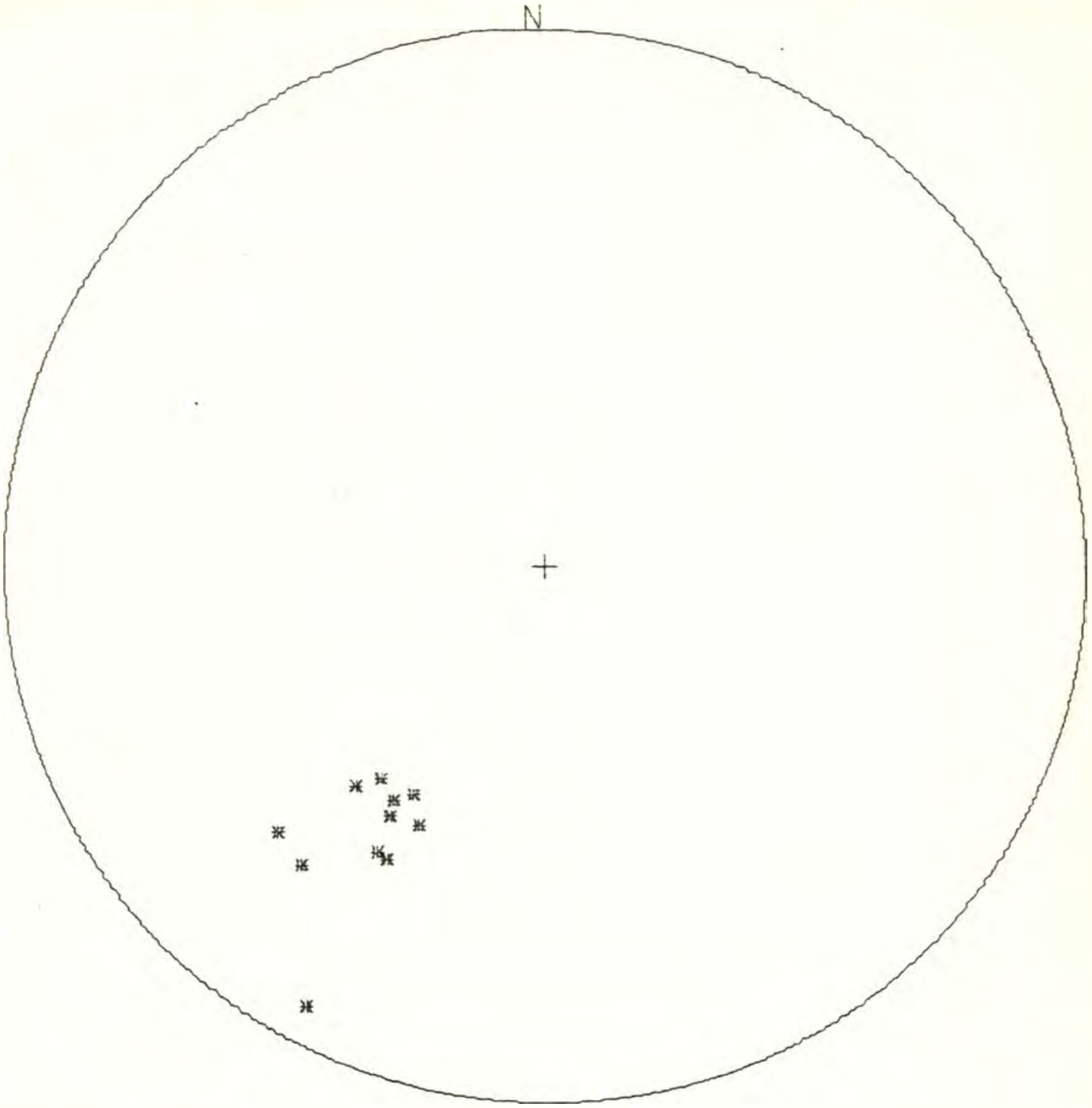
77-07B, NRM TOUTLE RIVER 2

SAMPLE NUMBER	DECLINATION	INCLINATION
043	220.40	-45.38
044	210.19	-38.33
045	205.76	-45.48
046	212.72	-47.02
047	209.76	-49.54
048	211.53	-44.67
049	208.07	-38.08
050	217.31	-48.88
051	208.26	-7.70
052	218.96	-29.28
053	224.93	-30.89

R= 10.73617 DECLINATION= 213.50 INCLINATION= -38.93

ALPHA= 7.51 DELTA= 12.57 KAPPA= 37.90

SITE LATITUDE= 46.38 SITE LONGITUDE=-122.63



77-07B. NRM TOUTLE RIVER 2

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-07B, 500 OE

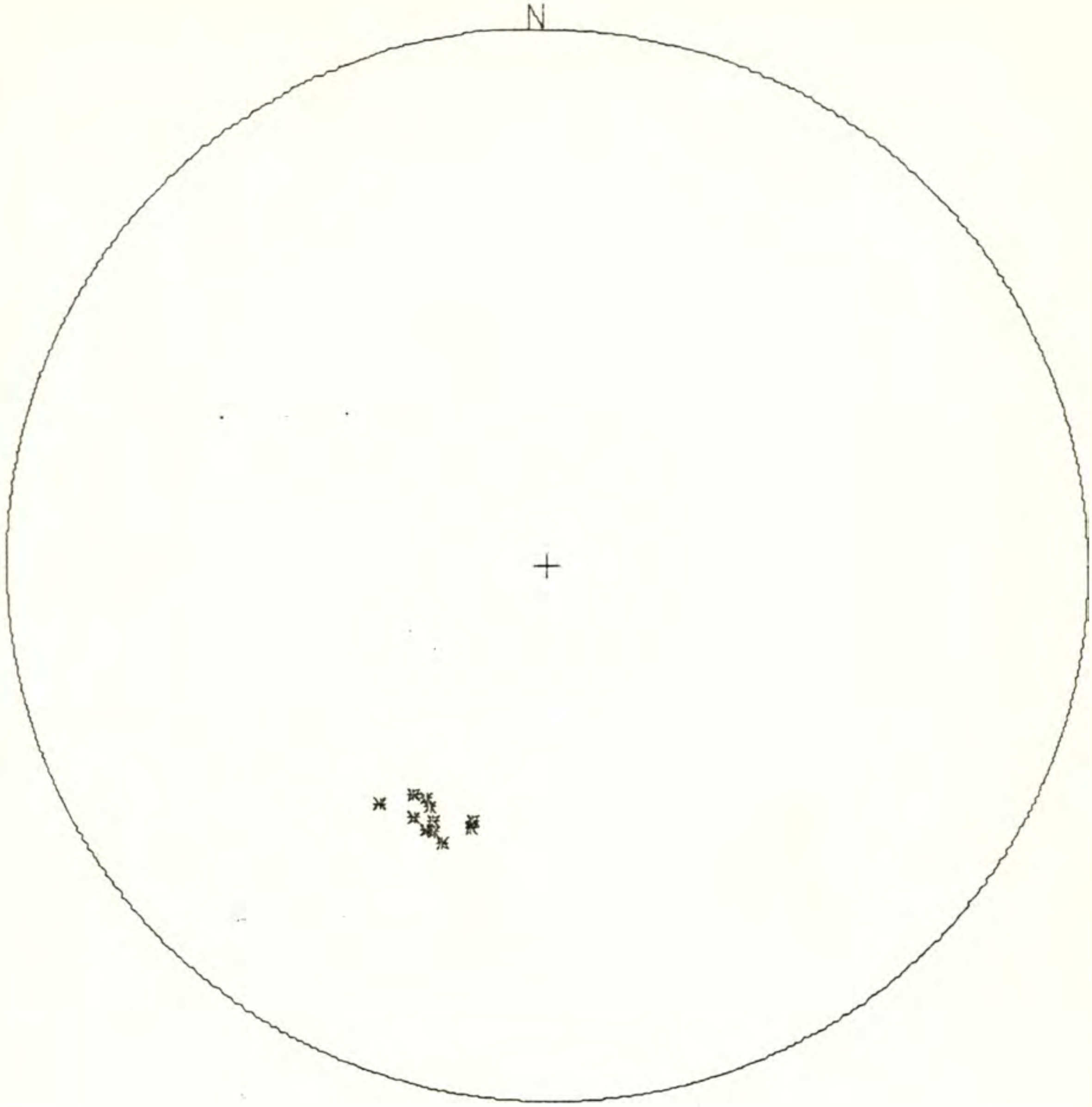
SAMPLE NUMBER	DECLINATION	INCLINATION
043	214.85	-44.80
044	202.93	-45.07
045	203.94	-46.66
046	207.80	-45.77
047	205.73	-48.48
048	207.26	-49.52
049	200.64	-43.75
050	210.21	-49.04
051	204.47	-44.89
052	196.33	-48.85
053	196.25	-47.67

R= 10.97154 DECLINATION= 204.60 INCLINATION= -46.90

ALPHA= 2.44 DELTA= 4.12 KAPPA= 351.32

PLAT= 63.43 PLONG= 2.20 DELP = 2.03

DECLM= -3.15 STLAT= 46.38 STLONG=-122.63



77-07B, 500 ØE

FISHER ON SAMPLE DIRECTIONS

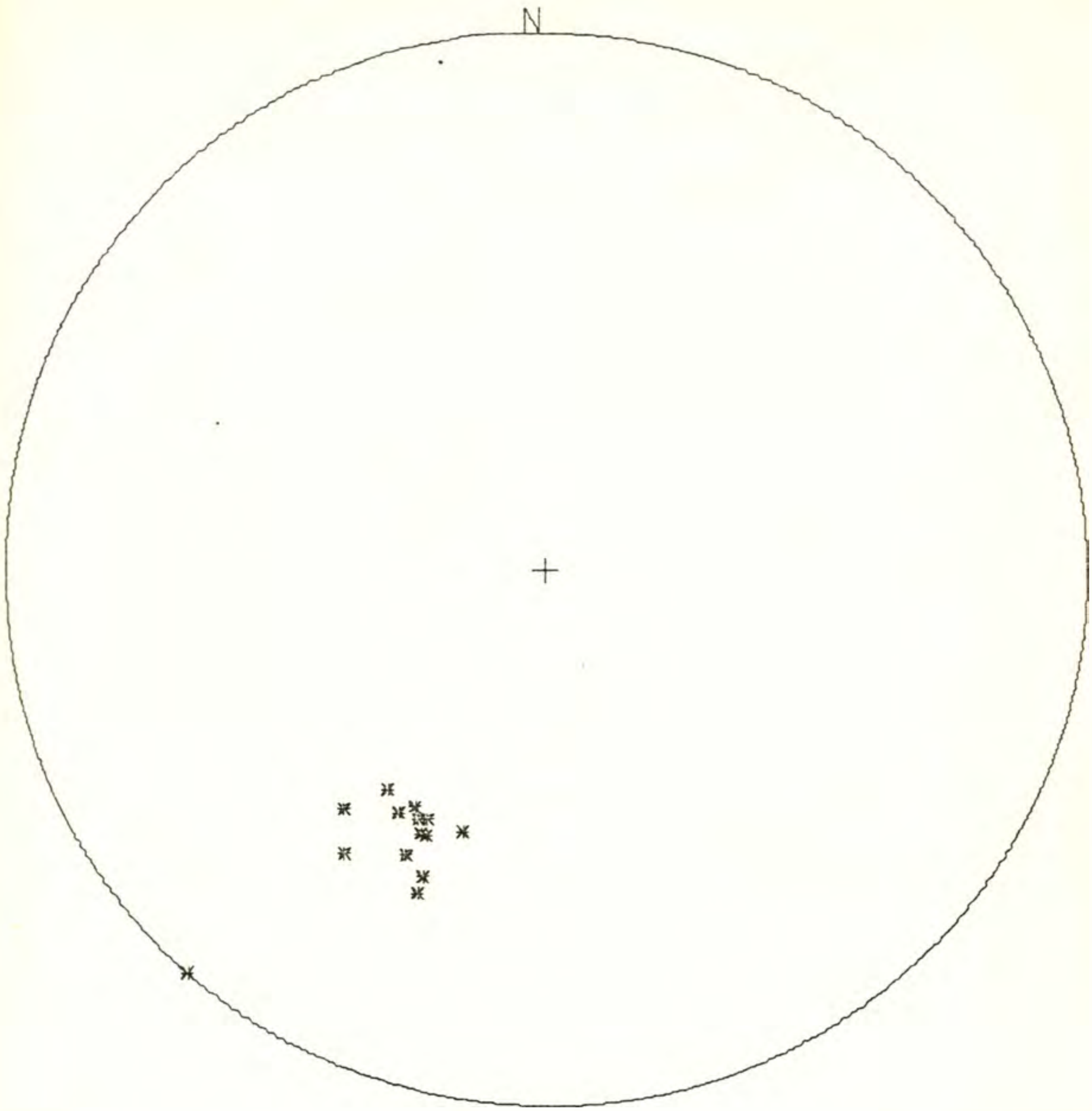
77-C8B, NRM TOUTLE RIVER 3

SAMPLE NUMBER	DECLINATION	INCLINATION
054	197.49	-47.43
055	203.97	-44.94
056	219.95	-41.54
057	205.27	-47.42
058	206.91	-46.74
059	215.27	-35.69
060	205.06	-44.81
061	206.09	-40.61
062	215.47	-48.45
063	221.41	0.09
064	208.61	-48.37
065	201.49	-35.55
066	210.92	-46.28
067	201.69	-38.42

R= 13.63982 DECLINATION= 208.89 INCLINATION= -40.89

ALPHA= 6.71 DELTA= 13.02 KAPPA= 36.09

SITE LATITUDE= 46.38 SITE LONGITUDE=-122.63



77-08B. NRM TOUTLE RIVER 3

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-08B, 200 AND 350 OE

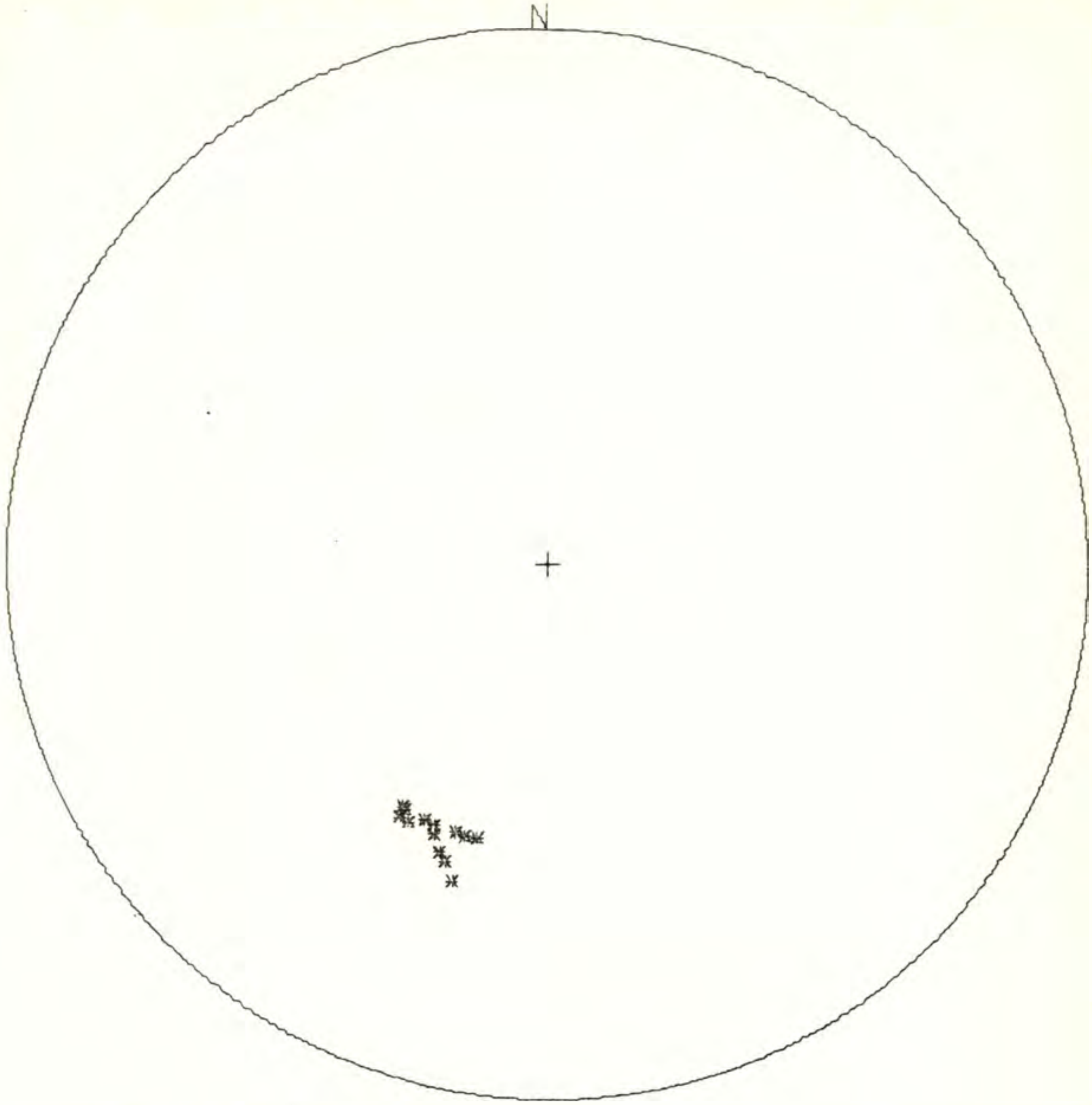
SAMPLE NUMBER	DECLINATION	INCLINATION
054	194.15	-46.10
055	196.77	-45.86
056	198.71	-46.03
057	209.72	-46.16
058	205.29	-46.14
059	202.36	-44.72
060	200.13	-42.24
061	203.10	-46.05
062	207.99	-44.56
064	209.84	-44.73
065	198.65	-41.02
066	210.48	-46.38
067	196.39	-38.25

R= 12.95924 DECLINATION= 202.50 INCLINATION= -44.61

ALPHA= 2.42 DELTA= 4.54 KAPPA= 294.44

PLAT= 63.11 PLONG= 8.02 DELP = 1.92

DECLM= -3.05 STLAT= 46.38 STLONG=-122.63



77-08B, 200 AND 350 OE

FISHER ON SAMPLE DIRECTIONS

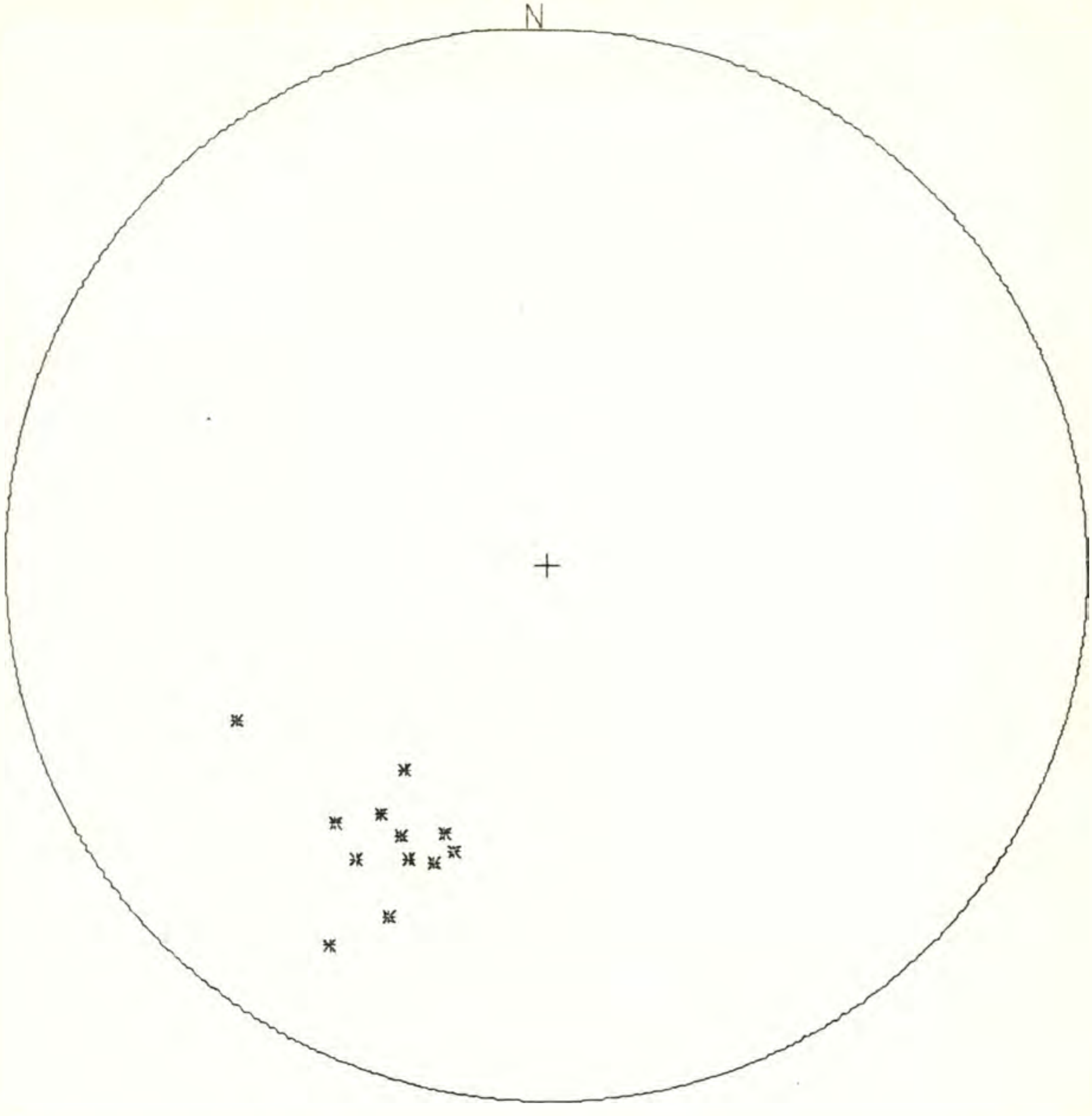
77-09B, NRM TOUTLE RIVER 4

SAMPLE NUMBER	DECLINATION	INCLINATION
068	213.44	-43.72
069	208.08	-42.24
070	243.05	-36.38
325	214.34	-51.70
326	218.92	-38.12
327	204.79	-39.33
328	200.76	-45.54
329	197.81	-43.17
331	212.54	-35.19
332	204.04	-28.93
333	200.62	-40.26
334	209.52	-19.73

R= 11.74099 DECLINATION= 210.65 INCLINATION= -39.29

ALPHA= 6.74 DELTA= 11.93 KAPPA= 42.47

SITE LATITUDE= 46.38 SITE LONGITUDE=-122.63



77-09B, NRM TØUTLE RIVER 4

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-09B 300 OE

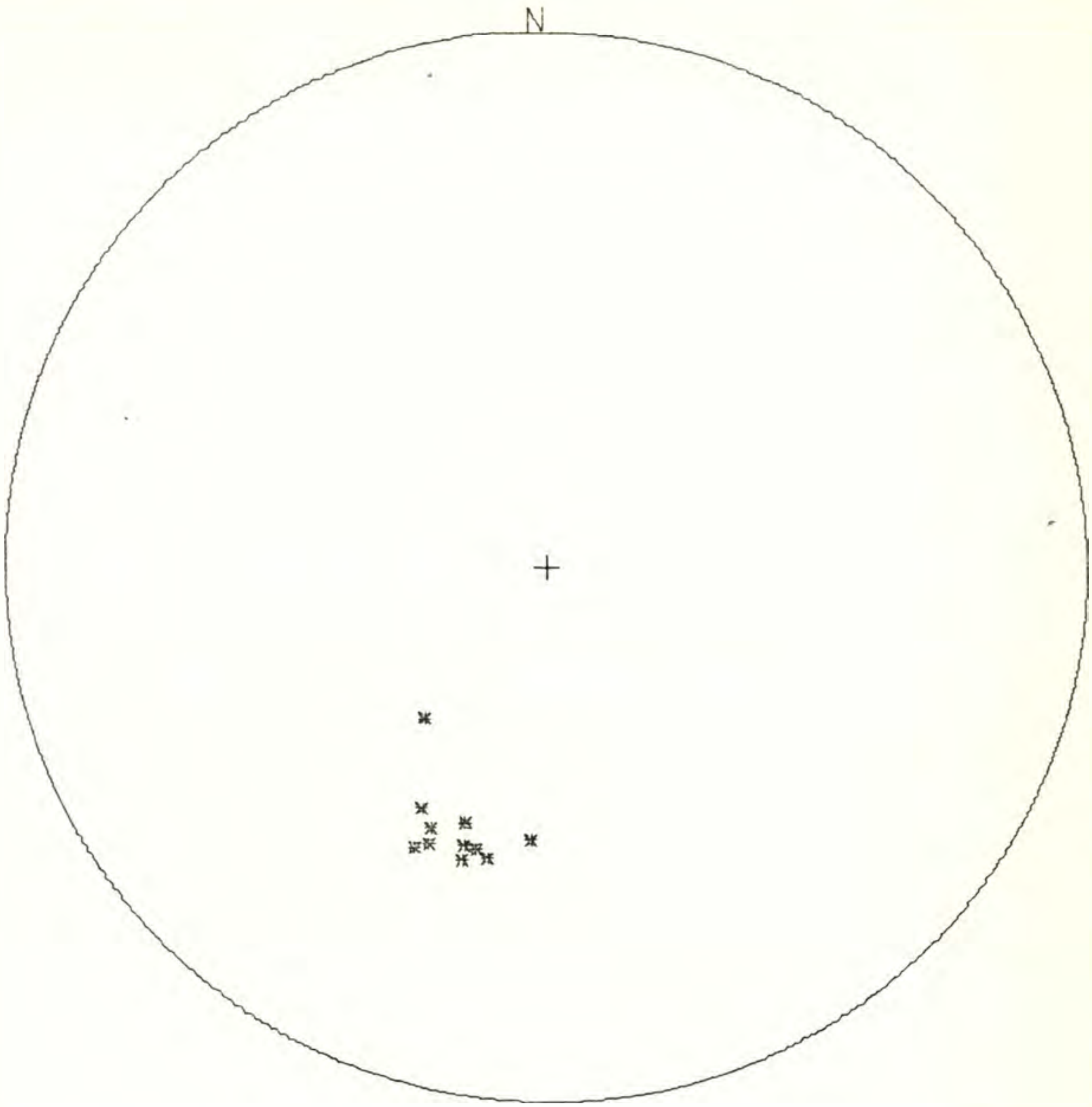
SAMPLE NUMBER	DECLINATION	INCLINATION
068	207.09	-48.04
069	202.91	-43.14
070	205.09	-41.71
325	218.55	-60.44
326	203.72	-45.72
327	197.62	-48.35
328	194.07	-44.70
329	183.45	-47.52
331	196.07	-42.49
332	191.59	-43.80
333	196.40	-44.81

R= 10.90569 DECLINATION= 199.19 INCLINATION= -46.72

ALPHA= 4.45 DELTA= 7.51 KAPPA= 106.04

PLAT= 66.20 PLONG= 11.38 DELP = 3.70

DECLM= -5.74 STLAT= 46.38 STLONG=-122.63



77-09B 300 OE

FISHER ON SAMPLE DIRECTIONS

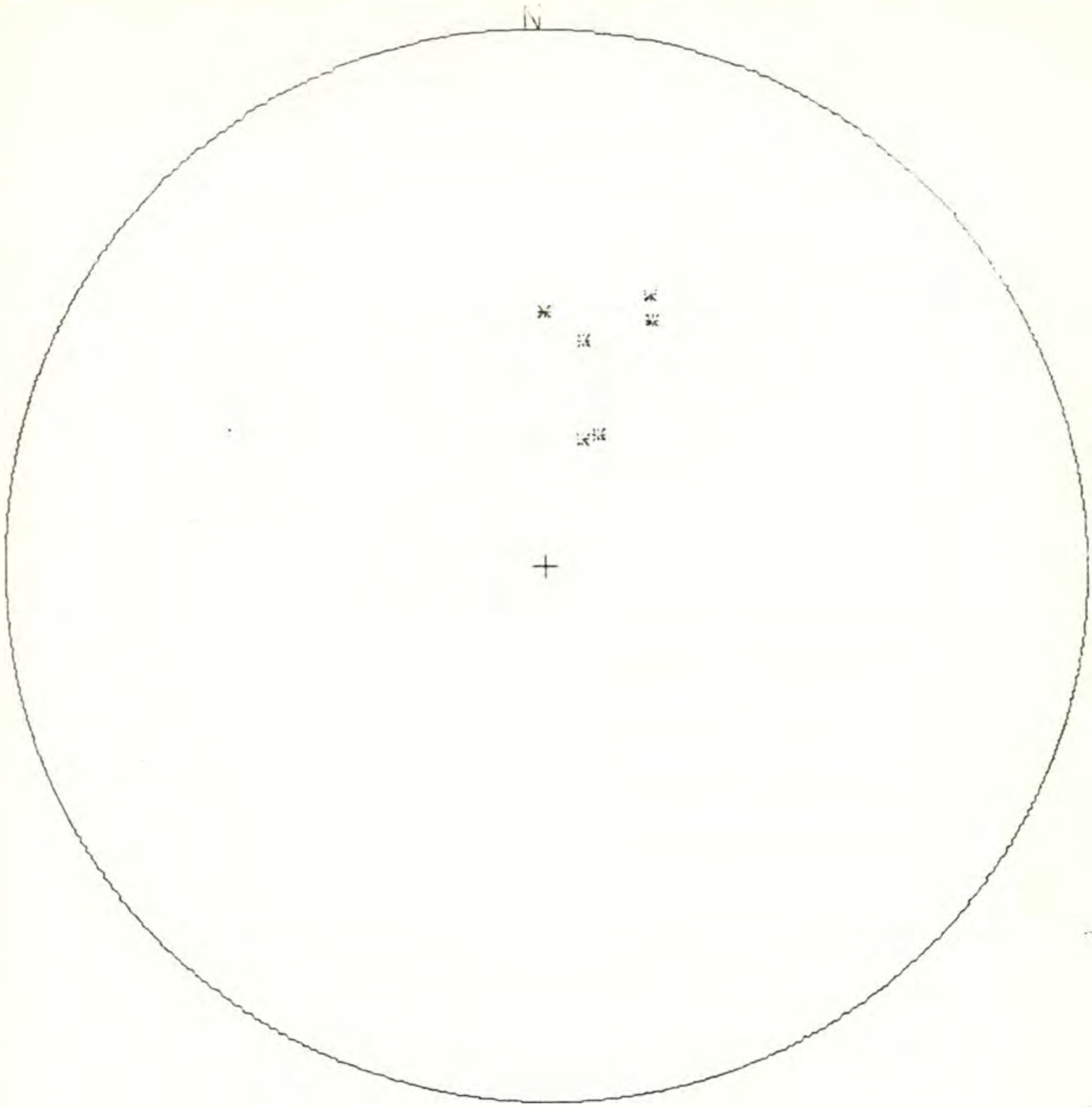
77-10B, NRM COWEMAN RIVER 1

SAMPLE NUMBER	DECLINATION	INCLINATION
071	0.22	50.84
072	21.48	44.73
073	16.62	69.92
074	22.52	68.39
075	9.91	54.82
076	23.87	48.50

R= 5.89375 DECLINATION= 15.49 INCLINATION= 56.49

ALPHA= 9.87 DELTA= 10.80 KAPPA= 47.06

SITE LATITUDE= 46.15 SITE LONGITUDE=-122.63



77-10B. NRM COWEMAN RIVER 1

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-10B, 200 OE

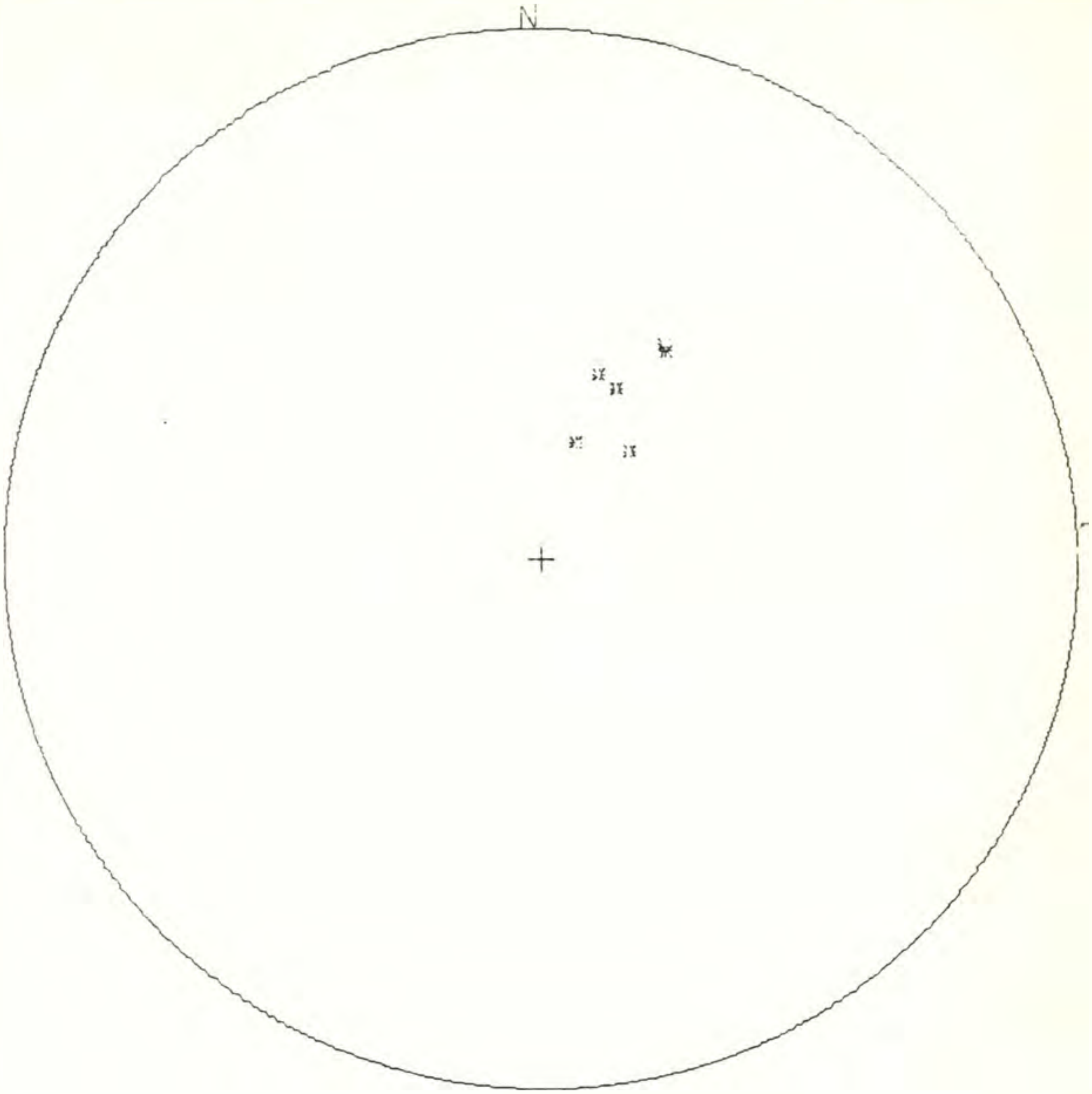
SAMPLE NUMBER	DECLINATION	INCLINATION
071	30.79	52.32
072	29.61	51.42
073	17.05	71.52
074	39.59	68.69
075	17.42	60.22
076	23.85	61.25

R= 5.93751 DECLINATION= 26.68 INCLINATION= 61.10

ALPHA= 7.54 DELTA= 8.28 KAPPA= 80.01

PLAT= 70.54 PLONG= -30.47 DELP = 8.86

DECLM= 11.56 STLAT= 46.15 STLONG=-122.63



77-10B. 200 OE

FISHER ON SAMPLE DIRECTIONS

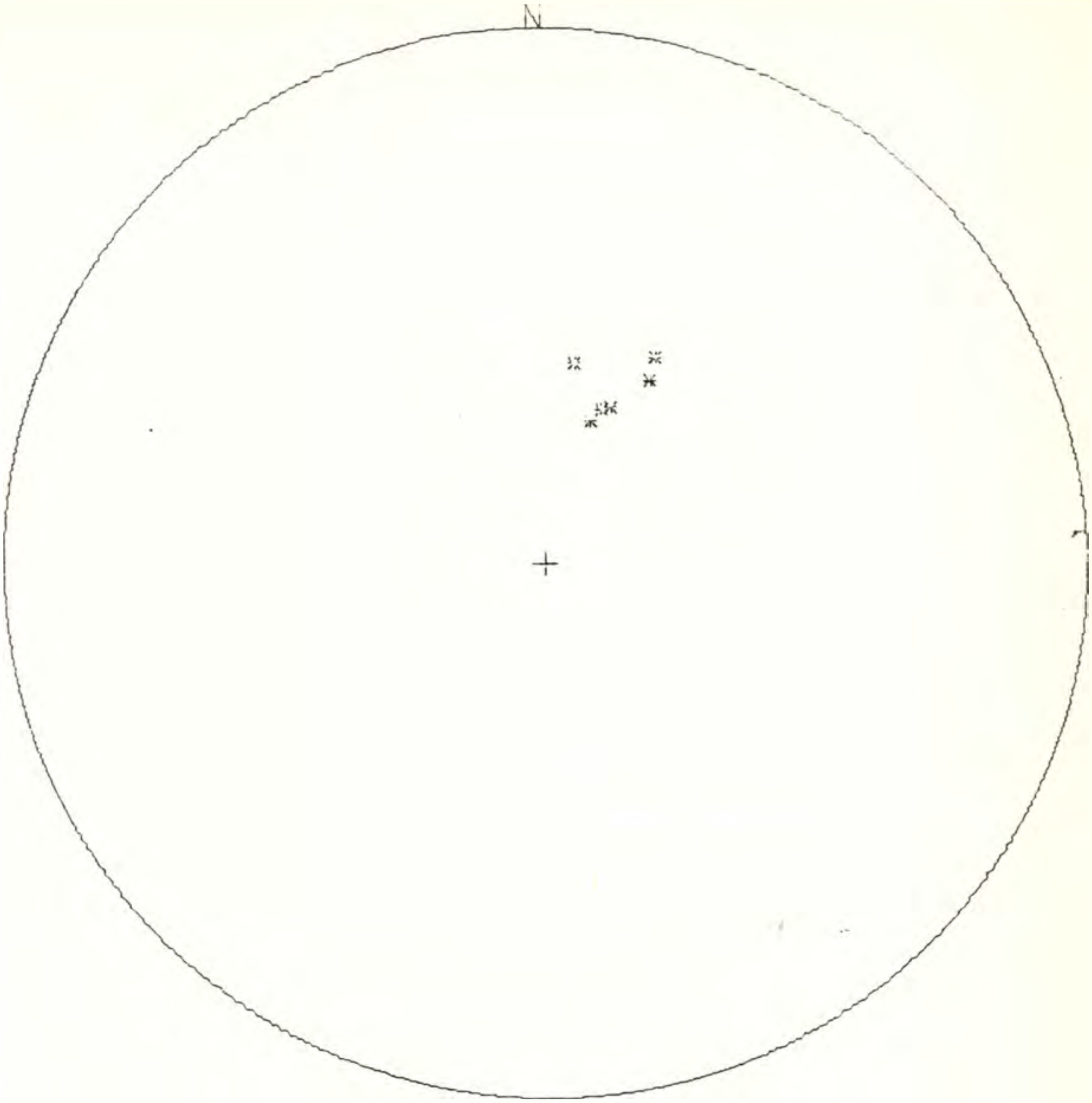
77-11B, NRM COWEMAN RIVER 2

SAMPLE NUMBER	DECLINATION	INCLINATION
077	29.94	57.70
078	17.55	67.26
079	20.01	64.97
080	28.17	54.10
081	22.86	64.12
082	8.34	58.85

R= 5.96879 DECLINATION= 21.53 INCLINATION= 61.37

ALPHA= 5.31 DELTA= 5.85 KAPPA= 160.19

SITE LATITUDE= 46.15 SITE LONGITUDE=-122.63



77-11B. NRM COWEMAN RIVER 2

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-11B, 200 OE

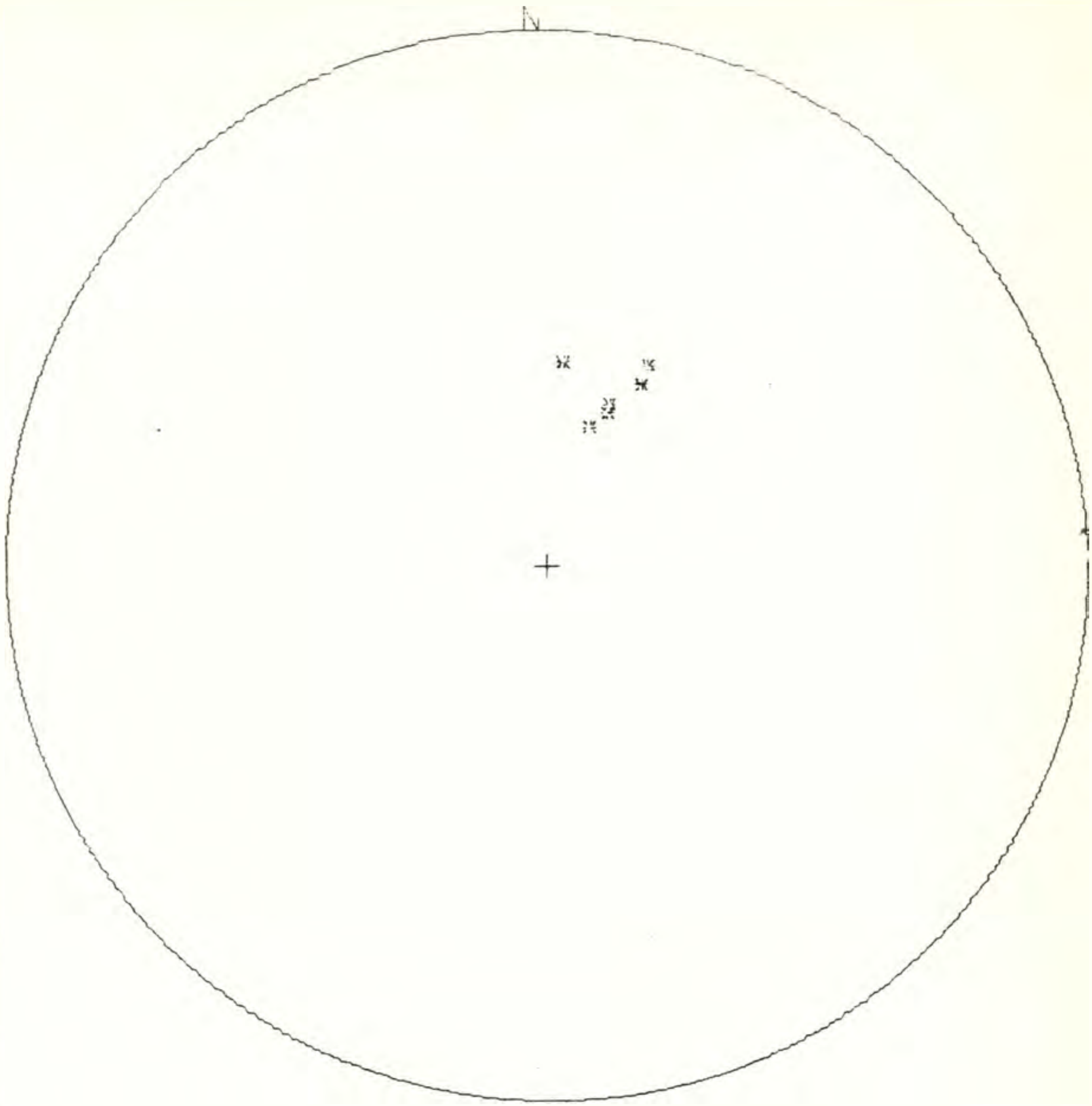
SAMPLE NUMBER	DECLINATION	INCLINATION
077	27.83	58.57
078	17.85	67.98
079	21.56	63.52
080	27.13	55.43
081	21.81	64.79
082	5.30	58.54

R= 5.97029 DECLINATION= 20.42 INCLINATION= 61.70

ALPHA= 5.18 DELTA= 5.70 KAPPA= 168.32

PLAT= 75.12 PLONG= -27.29 DELP = 6.19

DECLM= 8.01 STLAT= 46.15 STLONG=-122.63



77-11B. 200 OE

FISHER ON SAMPLE DIRECTIONS

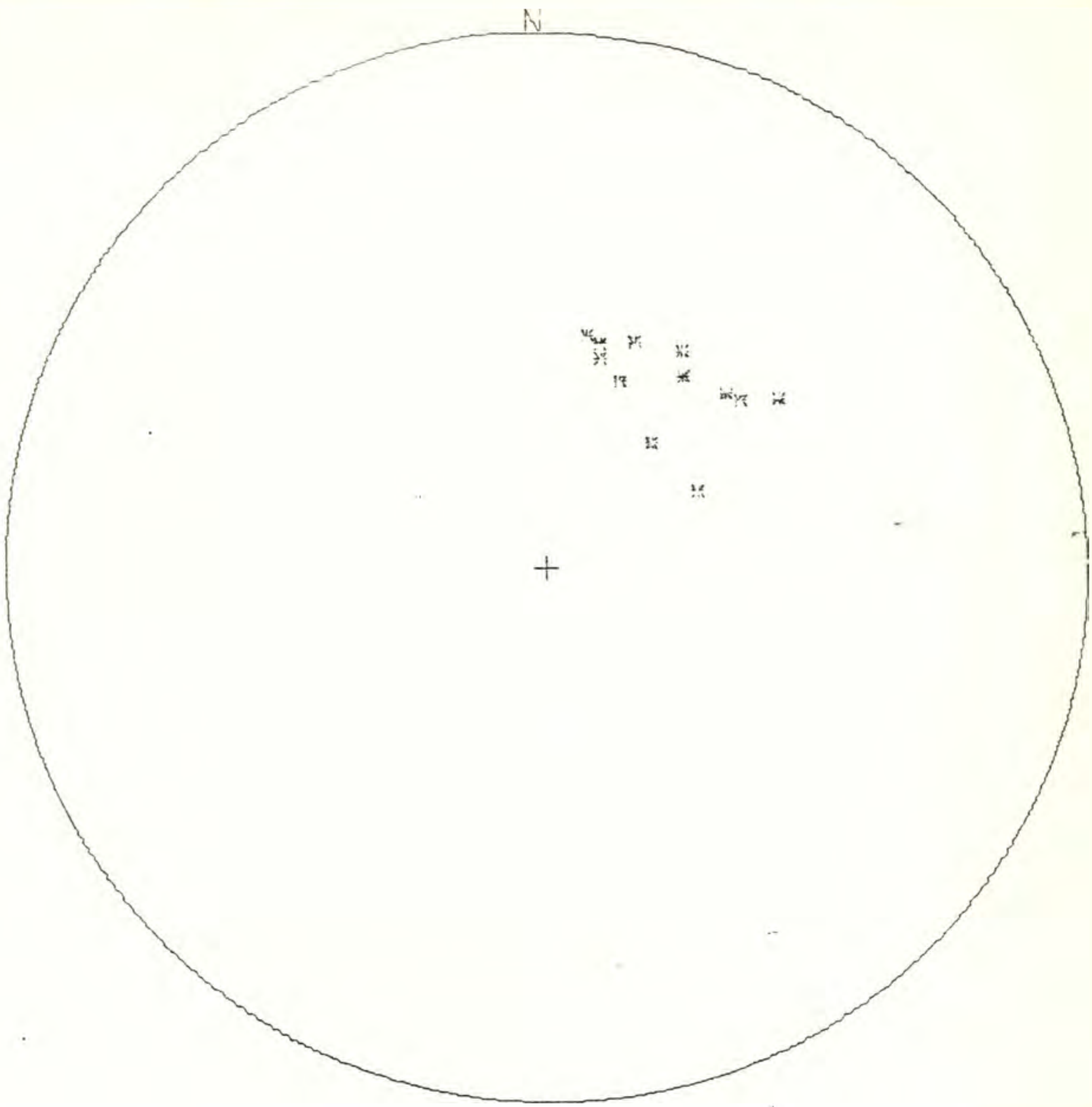
77-12B, NRM COWEMAN RIVER 3

SAMPLE NUMBER	DECLINATION	INCLINATION
083	35.43	53.87
084	63.10	64.38
085	21.54	59.15
086	48.94	50.73
087	21.45	52.76
088	40.05	65.13
089	13.73	54.52
090	10.24	53.70
091	14.60	56.81
092	53.86	45.76
093	45.53	51.69
094	31.94	50.70

R= 11.79002 DECLINATION= 33.19 INCLINATION= 56.03

ALPHA= 6.05 DELTA= 10.73 KAPPA= 52.39

SITE LATITUDE= 46.15 SITE LONGITUDE=-122.65



77-12B. NRM COWEMAN RIVER 3

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-12B, 200 OE

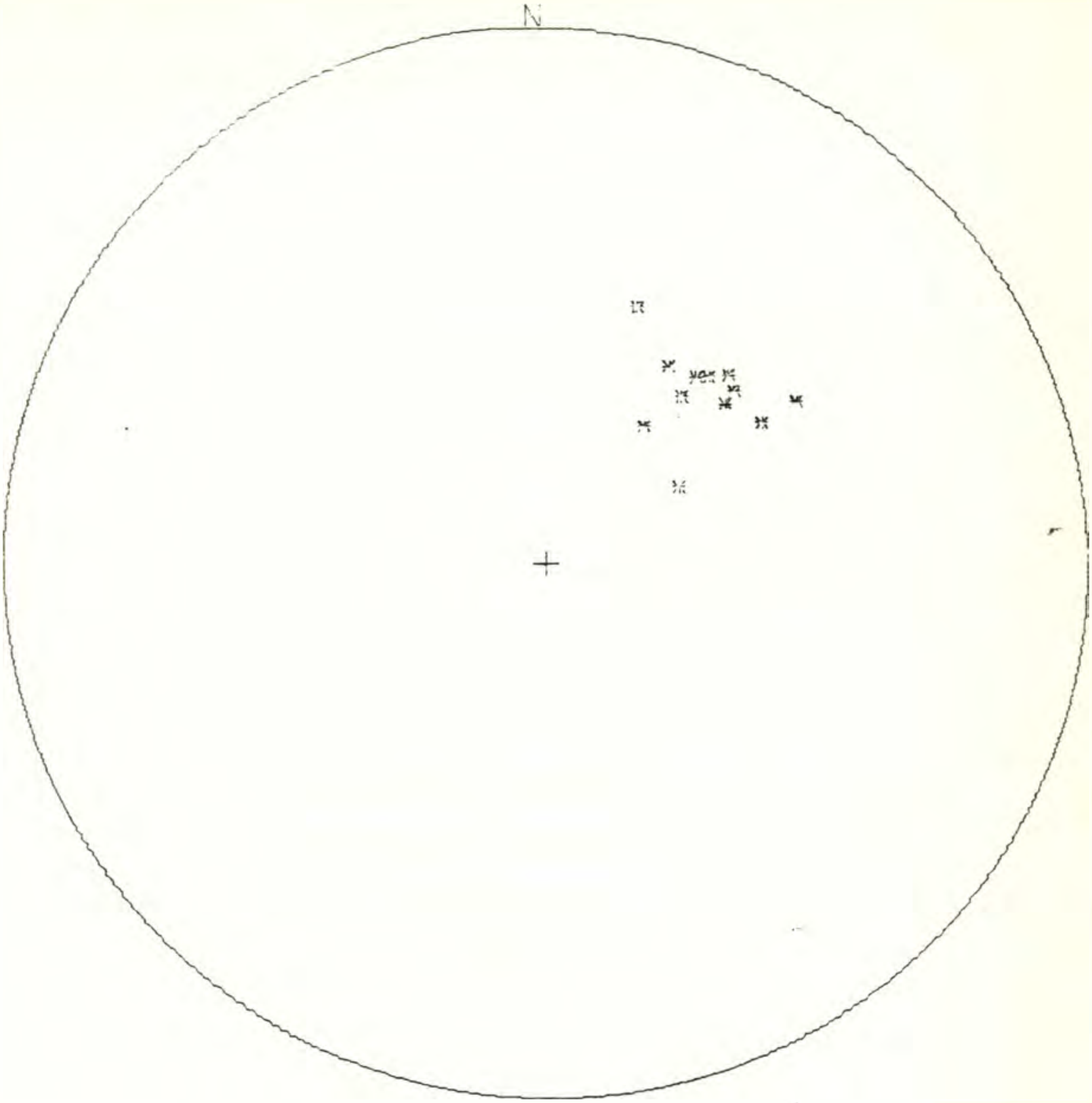
SAMPLE NUMBER	DECLINATION	INCLINATION
083	48.13	53.17
084	59.70	66.83
085	19.54	47.79
086	56.69	50.46
087	38.60	53.43
088	38.74	57.16
089	43.97	49.76
090	40.83	51.82
091	35.43	64.37
092	56.83	44.03
093	47.08	50.88
094	32.07	54.34

R= 11.85095 DECLINATION= 43.01 INCLINATION= 54.18

ALPHA= 5.09 DELTA= 9.04 KAPPA= 73.80

PLAT= 55.80 PLONG= -28.67 DELP = 5.02

DECLM= 7.14 STLAT= 46.15 STLONG=-122.65



77-12B. 200 OE

FISHER ON SAMPLE DIRECTIONS

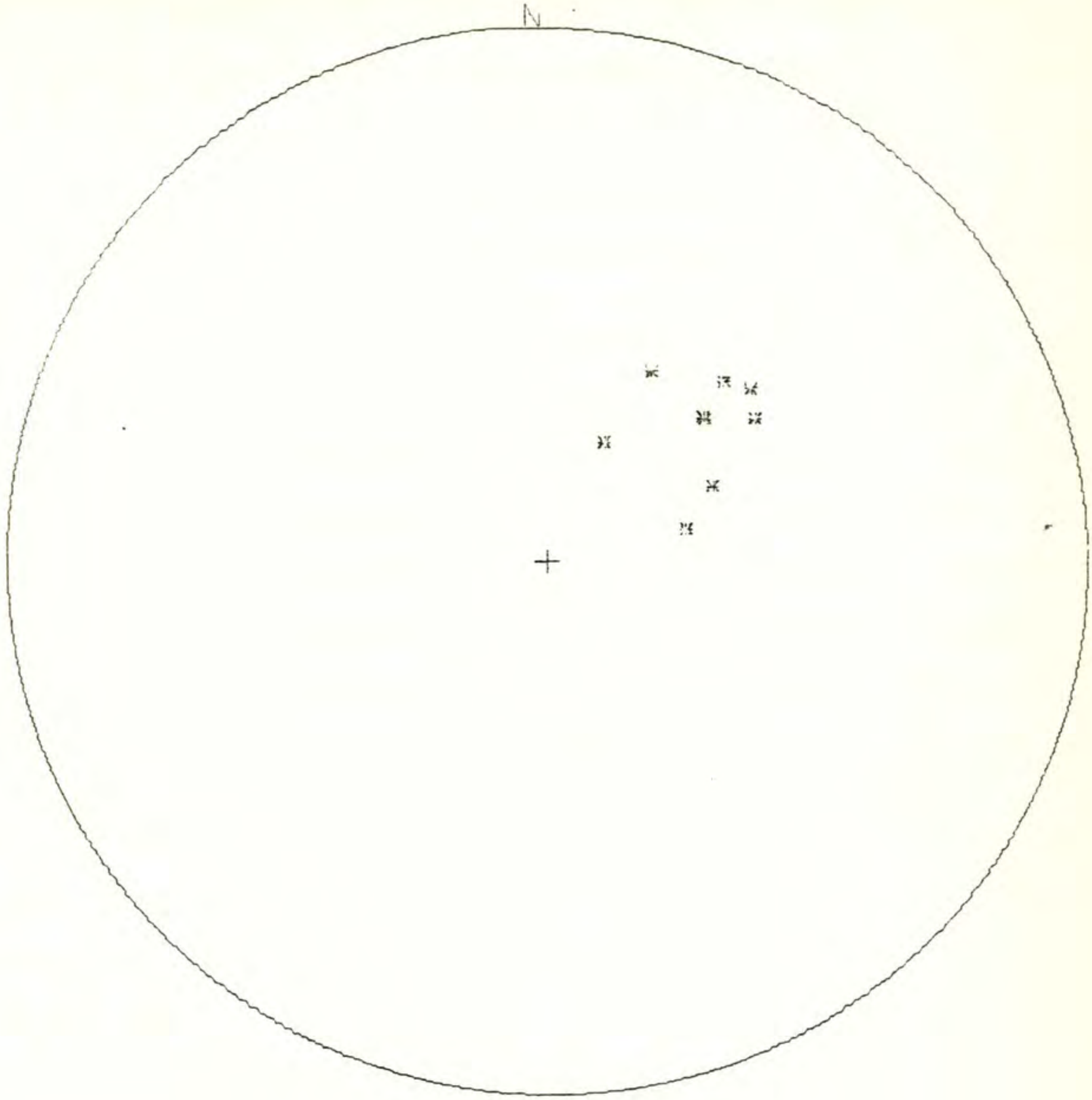
77-13B, NRM COWEMAN RIVER 4

SAMPLE NUMBER	DECLINATION	INCLINATION
095	66.00	62.24
096	48.20	57.50
097	26.32	69.87
098	28.96	56.50
099	47.53	57.37
100	55.83	51.09
101	49.82	48.60
102	77.30	68.48
103	44.57	50.99

R= 8.86207 DECLINATION= 49.03 INCLINATION= 58.78

ALPHA= 6.82 DELTA= 10.04 KAPPA= 58.00

SITE LATITUDE= 46.15 SITE LONGITUDE=-122.65



77-13B. NRM COWEMAN RIVER 4

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-13B, 200 OE

DIP AZIMUTH = 144.0   DIP ANGLE =   4.0

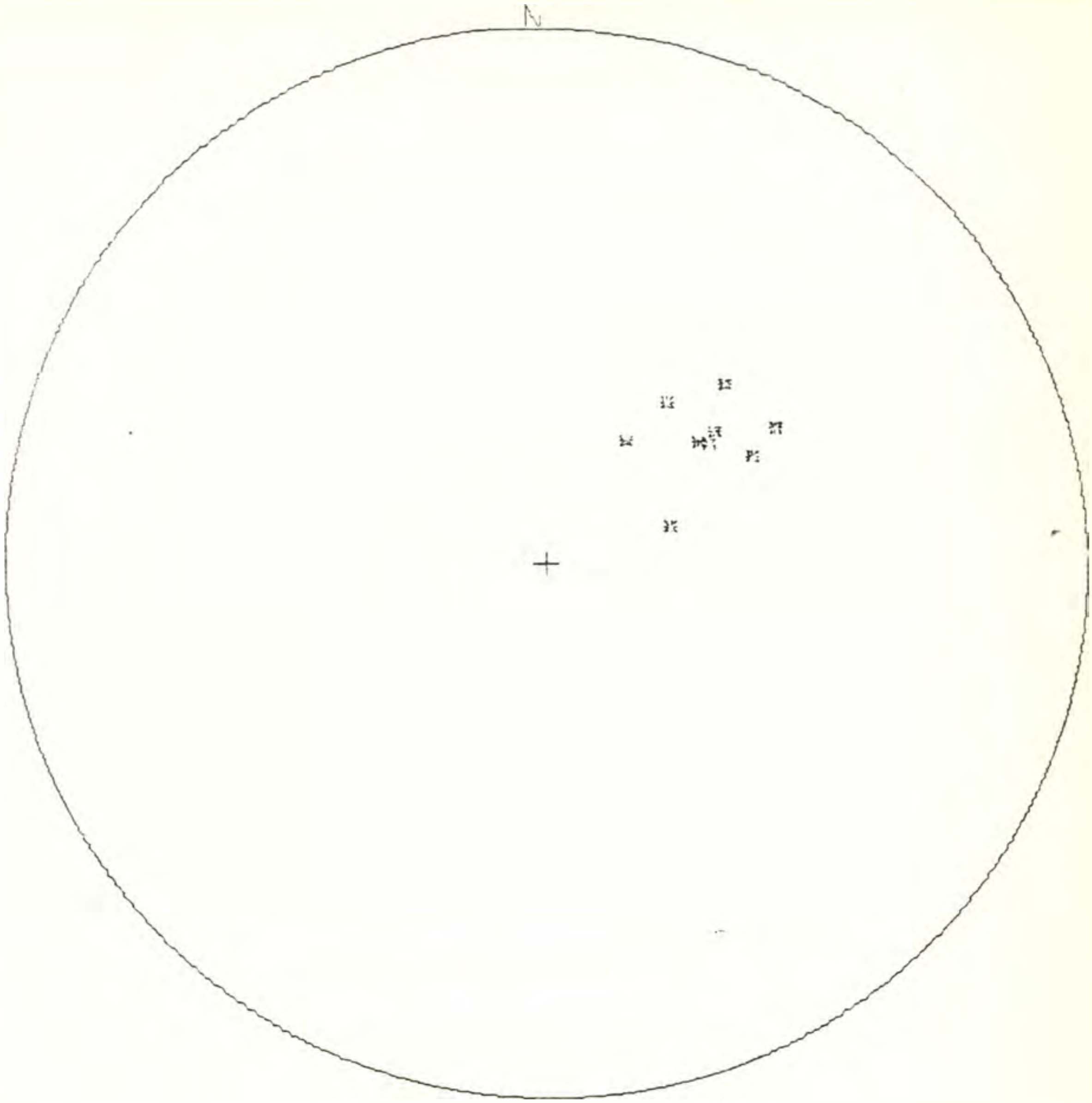
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
095	44.28	59.97	51.23	60.41
096	47.15	59.12	53.87	59.36
097	24.50	66.00	32.97	67.71
098	30.67	57.87	36.81	59.26
099	45.38	57.08	51.58	57.47
100	56.99	55.08	62.65	54.67
101	54.55	49.39	59.20	49.19
102	62.22	71.43	73.49	70.47
103	39.92	50.18	44.69	50.99

R=   8.89830   DECLINATION= 51.74   INCLINATION= 59.29

ALPHA= 5.84   DELTA= 8.62   KAPPA=   78.66

PLAT= 52.43   PLONG= -42.51   DELP = 6.55

DECLM= 8.75   STLAT= 46.15   STLONG=-122.65



77-13B. 200 OE

FISHER ON SAMPLE DIRECTIONS

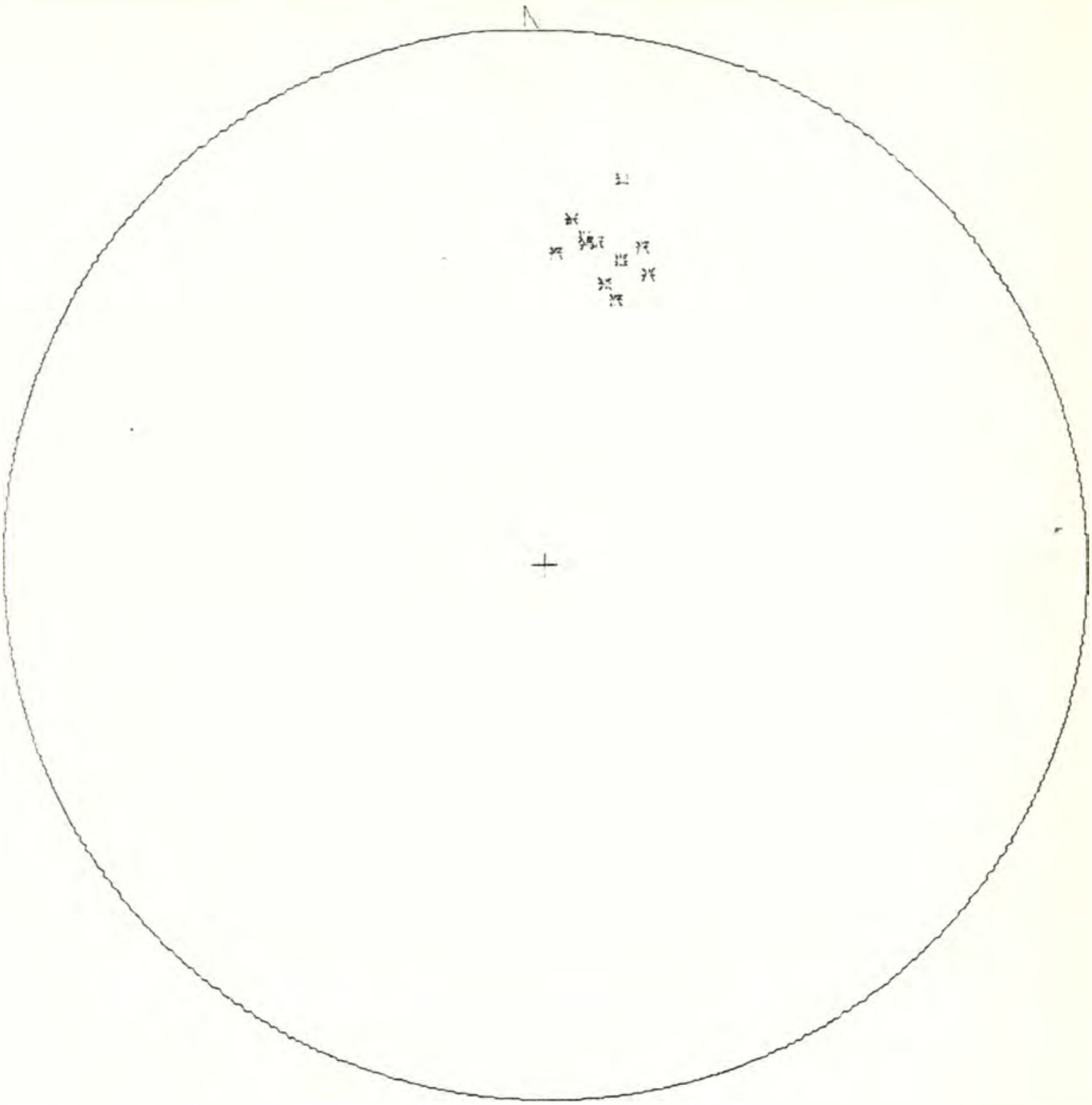
77-14B,NRM ROSE VALLEY

SAMPLE NUMBER	DECLINATION	INCLINATION
103	4.79	35.46
104	11.68	27.41
105	2.38	41.25
106	7.84	39.48
107	7.26	38.31
108	9.57	38.79
109	12.38	45.24
110	15.10	47.45
111	17.29	37.92
112	19.90	41.97
113	14.28	41.02

R= 10.93262 DECLINATION= 11.04 INCLINATION= 39.60

ALPHA= 3.76 DELTA= 6.35 KAPPA= 148.41

SITE LATITUDE= 46.10 SITE LONGITUDE=-122.85



77-14B.NRM ROSE VALLEY

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-14B, 300 OE

DIP AZIMUTH = 170.0 DIP ANGLE = 15.0

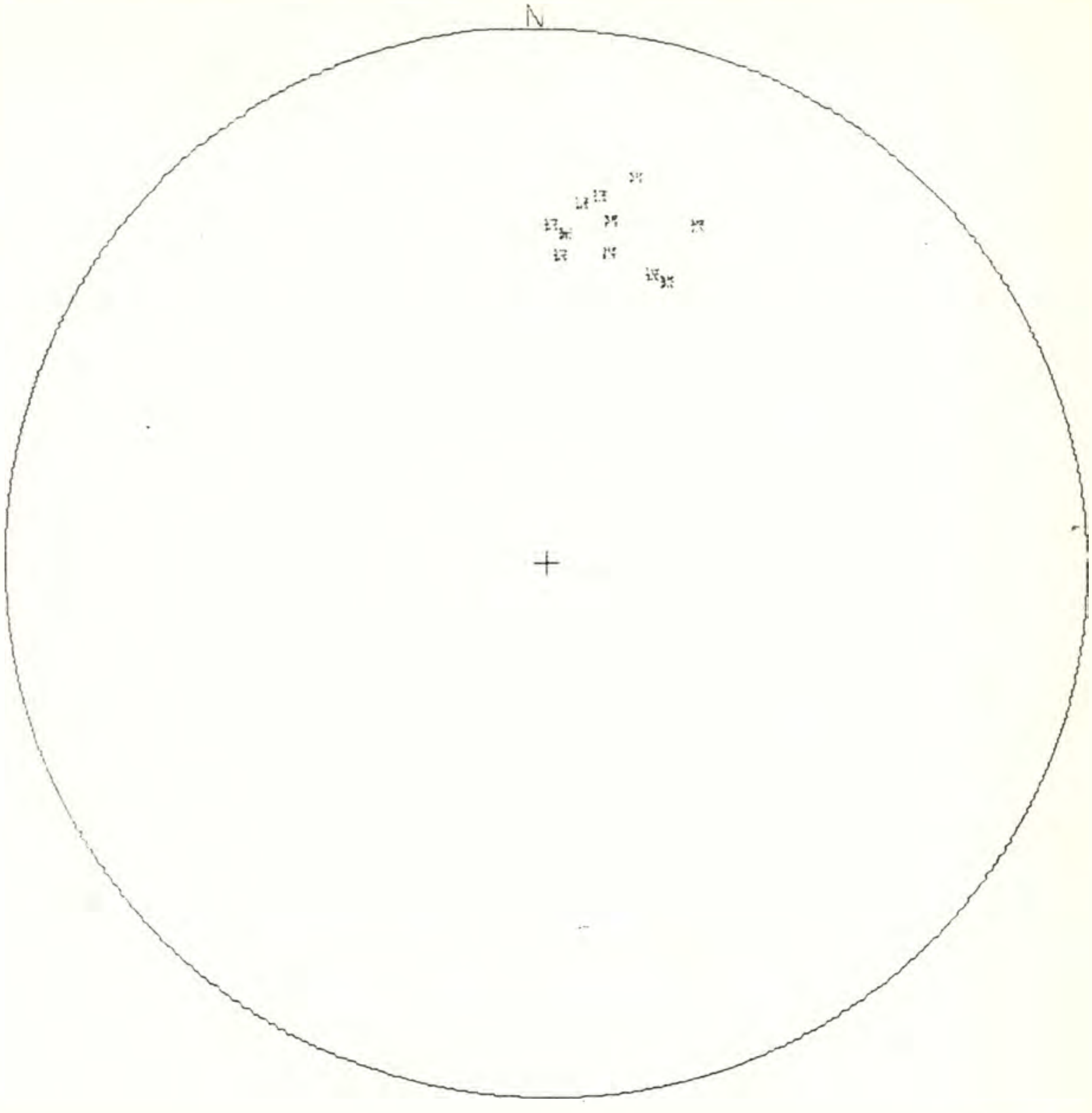
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
103	1.67	23.68	3.66	38.32
104	11.13	13.27	13.23	27.17
105	3.88	18.40	5.73	32.91
106	359.41	22.03	0.91	36.80
107	0.62	27.19	2.72	41.89
108	20.20	18.95	23.99	31.68
109	8.05	26.56	11.44	40.69
110	6.37	16.99	8.39	31.31
111	15.18	28.78	20.17	42.09
112	17.65	29.25	23.14	42.22
113	8.16	21.21	10.87	35.36

R= 10.89582 DECLINATION= 11.26 INCLINATION= 36.66

ALPHA= 4.68 DELTA= 7.89 KAPPA= 95.99

PLAT= 62.70 PLONG= 33.62 DELP = 3.20

DECLM= 5.47 STLAT= 46.10 STLONG=-122.85



77-14B. 300 OE

FISHER ON SAMPLE DIRECTIONS

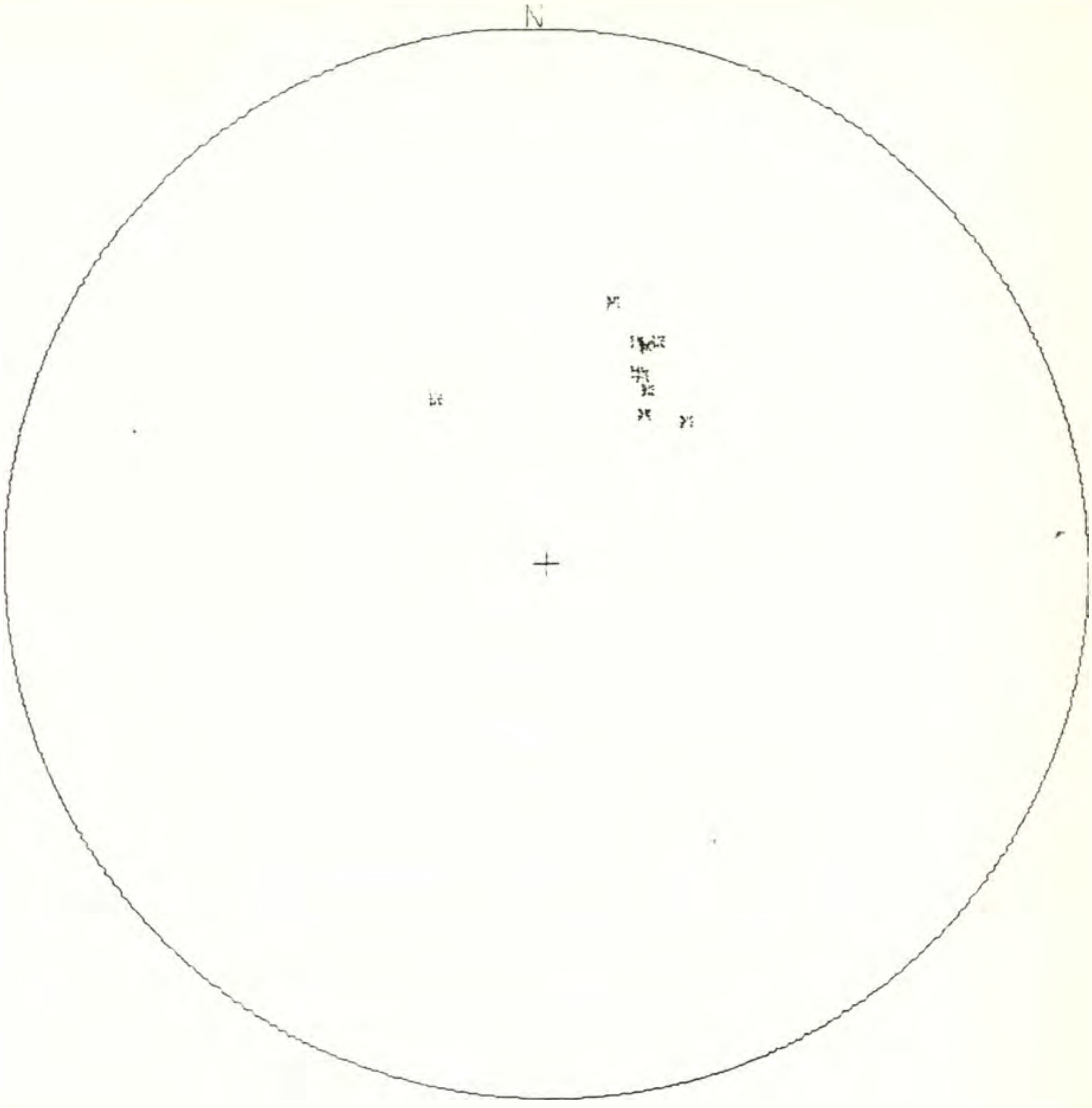
77-15B, NRM CARROLLS

SAMPLE NUMBER	DECLINATION	INCLINATION
114	24.46	52.91
115	326.63	59.71
116	25.09	53.17
117	26.91	57.63
118	30.28	59.10
119	25.19	57.33
120	22.07	52.99
121	33.30	62.87
122	14.39	48.30
123	44.41	59.61
124	26.43	51.60

R= 10.81515 DECLINATION= 22.35 INCLINATION= 57.17

ALPHA= 6.26 DELTA= 10.52 KAPPA= 54.10

SITE LATITUDE= 46.07 SITE LONGITUDE=-122.85



77-15B. NRM CARROLLS

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-15B, 200 OE

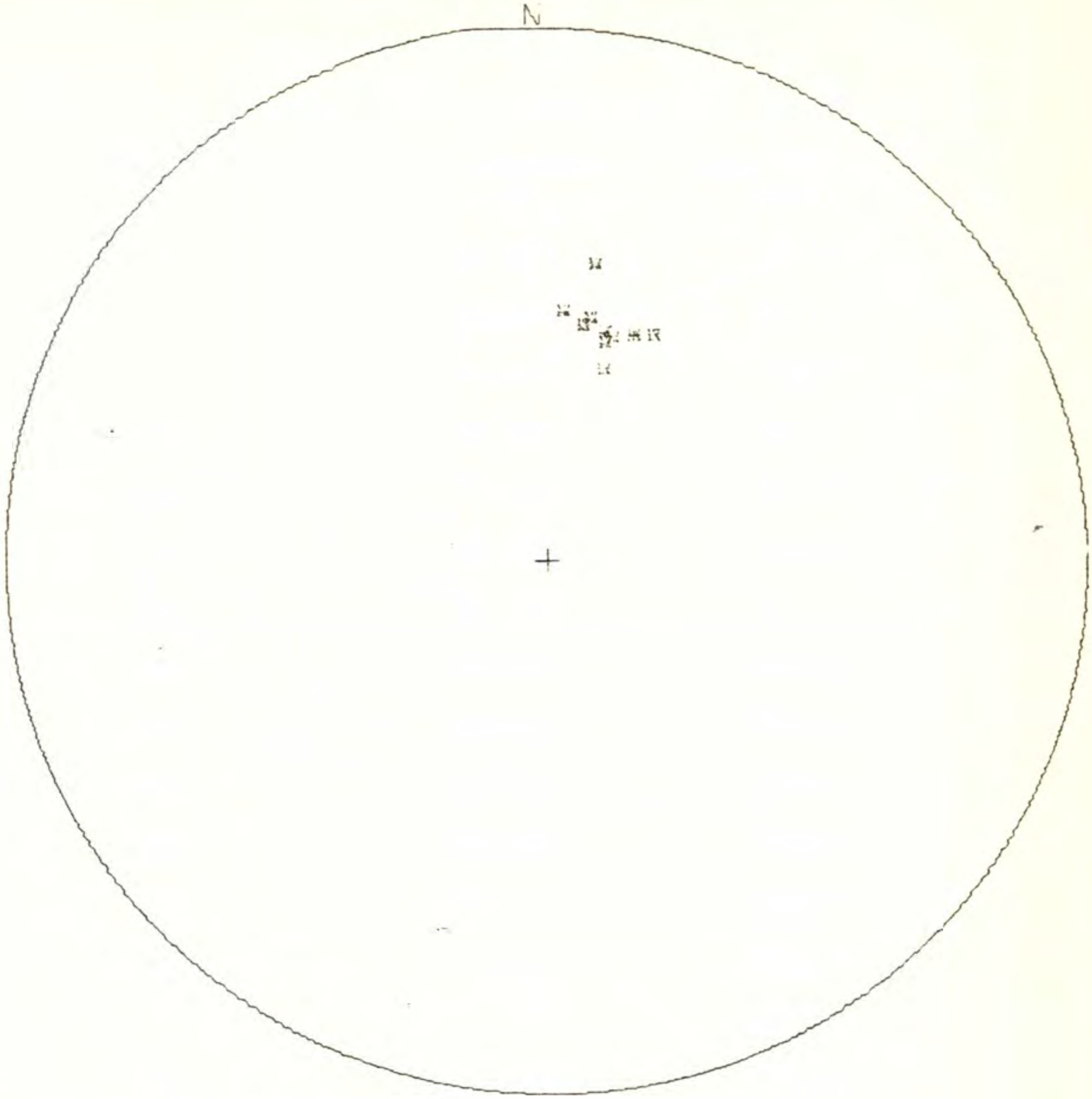
SAMPLE NUMBER	DECLINATION	INCLINATION
114	21.31	52.72
116	16.70	59.23
117	9.22	53.20
218	10.60	51.79
119	15.49	55.16
120	14.54	53.66
121	4.37	51.30
122	9.87	43.03
123	25.42	51.34
124	16.66	53.93

R= 9.95756 DECLINATION= 14.27 INCLINATION= 52.69

ALPHA= 3.33 DELTA= 5.28 KAPPA= 212.05

PLAT= 73.18 PLONG= 11.71 DELP = 3.16

DECLM= 4.59 STLAT= 46.07 STLONG=-122.85



77-15B. 200 OE

FISHER ON SAMPLE DIRECTIONS

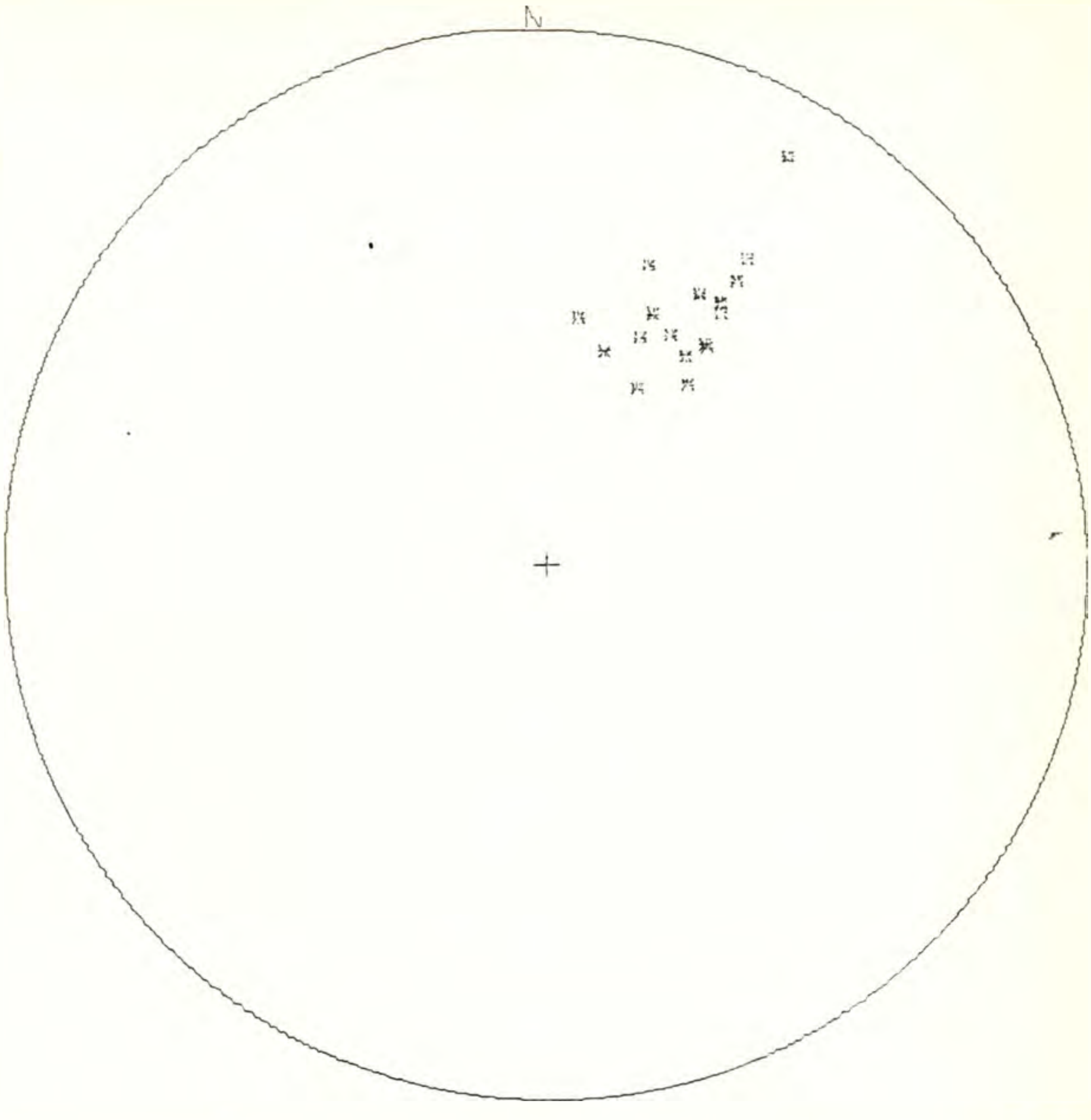
77-16B, NRM KALAMA RIVER 1

SAMPLE NUMBER	DECLINATION	INCLINATION
125	15.37	56.00
126	28.57	49.72
127	22.23	52.13
128	33.67	51.34
129	27.03	59.91
130	7.56	51.59
131	30.78	12.56
132	36.42	48.37
133	33.64	40.88
134	38.00	55.10
135	29.25	41.53
136	35.60	47.87
137	34.58	42.42
138	34.03	36.51
139	18.91	40.78
140	33.34	32.33
141	23.05	47.90

R= 16.62789 DECLINATION= 28.75 INCLINATION= 45.47

ALPHA= 5.50 DELTA= 12.01 KAPPA= 43.00

SITE LATITUDE= 46.05 SITE LONGITUDE=-122.63



77-16B. NRM KALAMA RIVER 1

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-16B, 150 OE

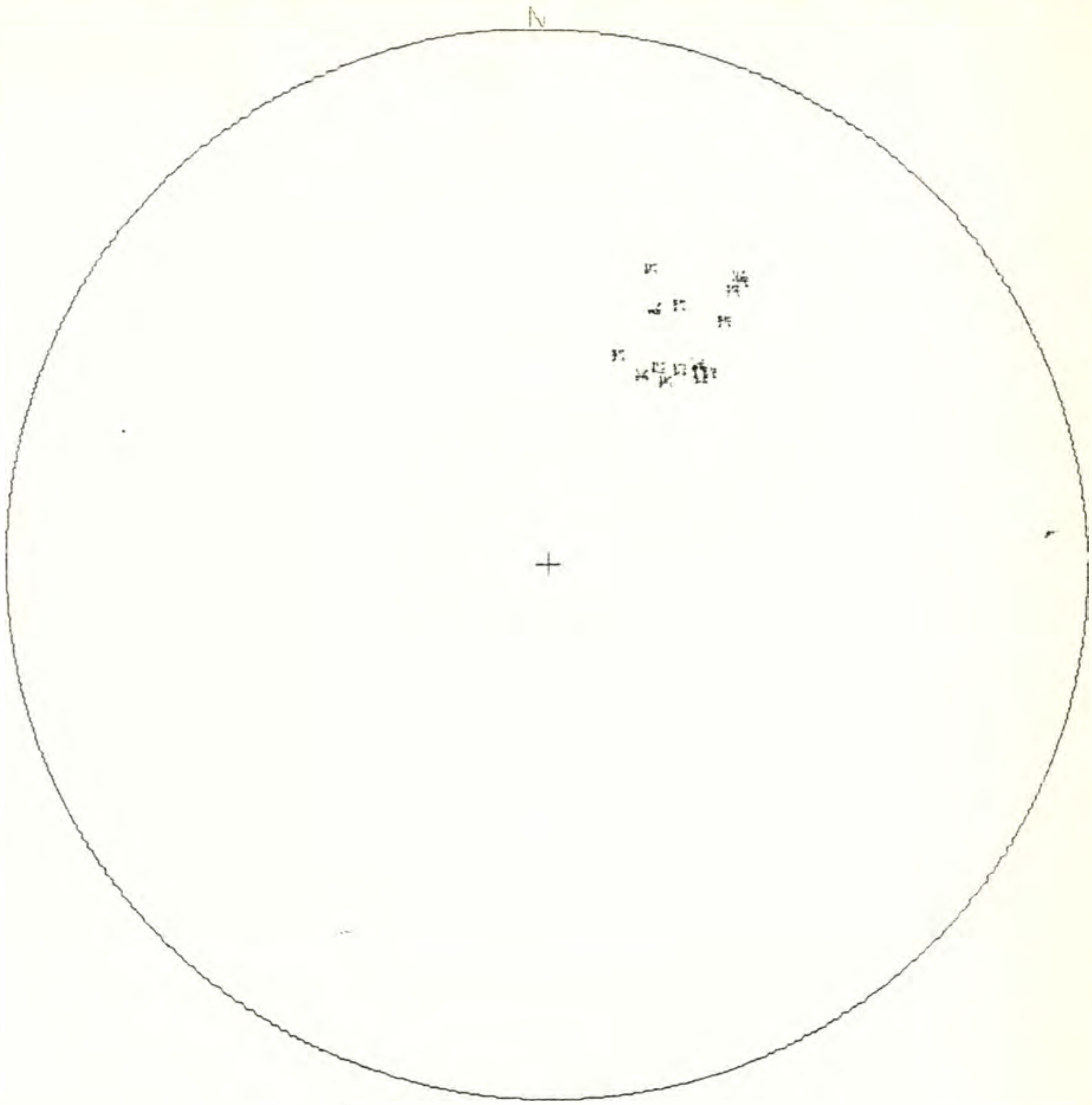
SAMPLE NUMBER	DECLINATION	INCLINATION
125	26.42	57.54
126	36.47	51.35
127	29.01	55.37
128	39.15	52.81
129	33.82	53.76
130	18.76	55.95
132	37.91	52.02
133	33.92	38.23
134	32.63	56.80
135	26.88	44.62
136	40.21	51.22
137	35.88	43.12
138	34.34	36.12
139	19.16	41.24
140	33.36	35.85
141	22.56	47.14

R= 15.82661 DECLINATION= 31.33 INCLINATION= 48.51

ALPHA= 3.99 DELTA= 8.44 KAPPA= 86.51

PLAT= 60.51 PLONG= -9.46 DELP = 3.44

DECLM= 5.24 STLAT= 46.05 STLONG=-122.63



77-16B, 150 OE

FISHER ON SAMPLE DIRECTIONS

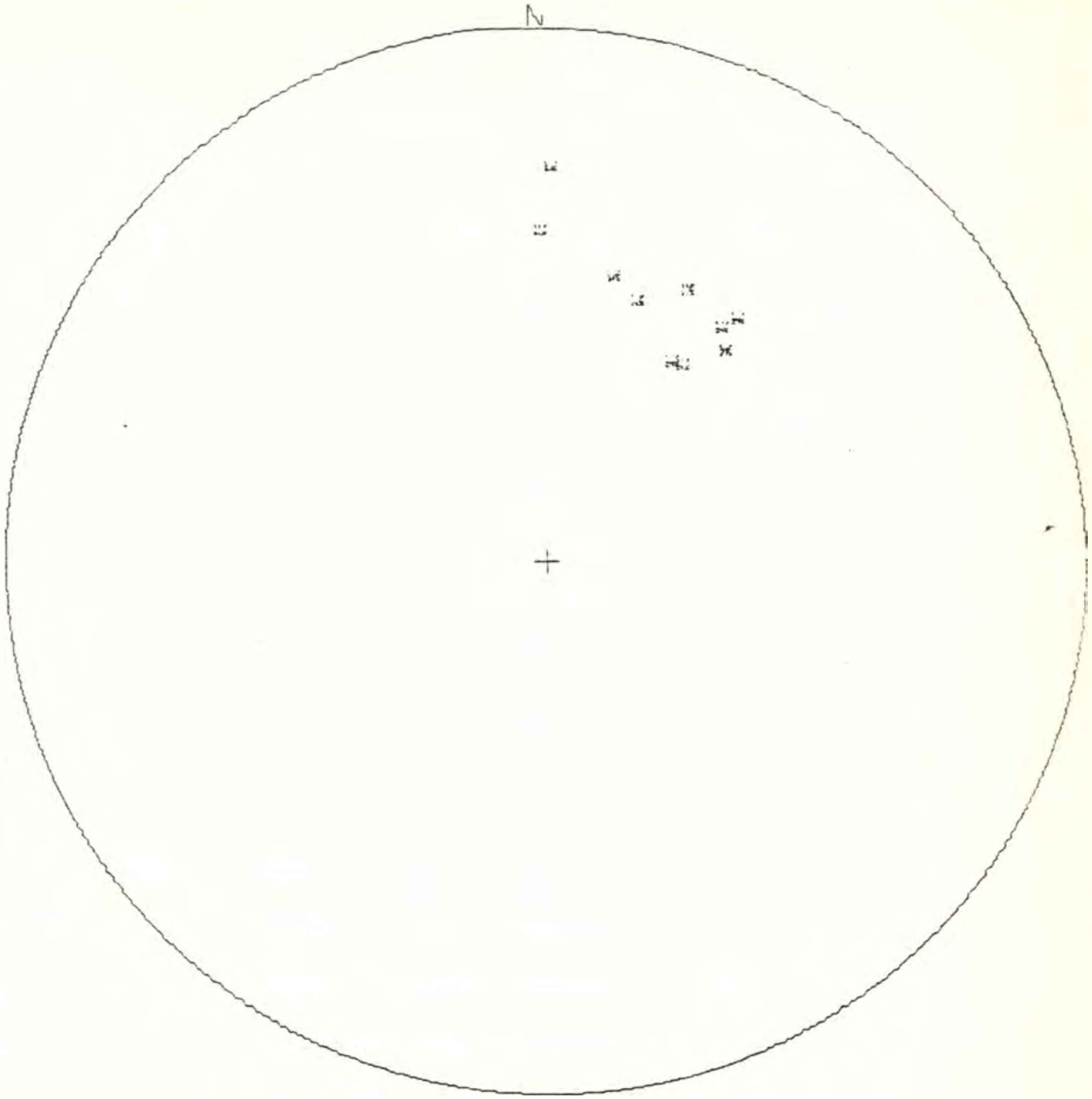
77-17B, NRM KALAMA RIVER 2

SAMPLE NUMBER	DECLINATION	INCLINATION
142	40.28	46.95
143	1.01	27.03
144	359.14	38.16
145	38.36	41.60
146	13.44	44.18
147	34.61	53.12
148	36.97	44.51
149	32.29	53.57
150	19.25	47.15
151	27.54	42.25

R= 9.74583 DECLINATION= 23.27 INCLINATION= 44.86

ALPHA= 8.23 DELTA= 12.95 KAPPA= 35.41

SITE LATITUDE= 46.05 SITE LONGITUDE=-122.63



77-17B. NRM KALAMA RIVER 2

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-17B, 250 OE

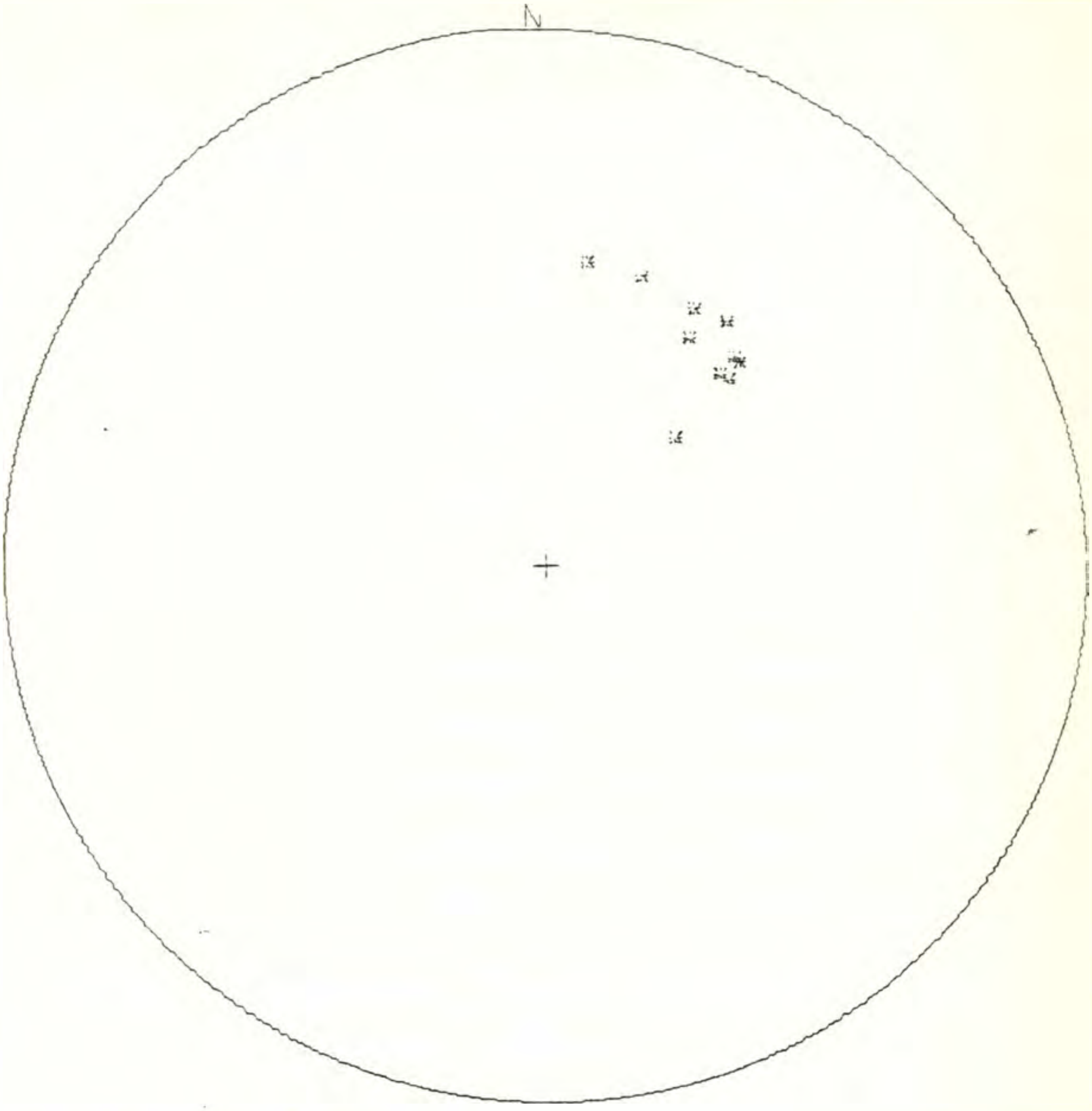
SAMPLE NUMBER	DECLINATION	INCLINATION
142	43.67	46.40
143	18.50	42.66
144	8.11	42.50
145	36.74	42.63
146	30.15	43.88
147	42.20	46.57
148	32.39	48.34
149	45.22	62.33
150	42.34	50.09
151	44.47	49.79

R= 9.85302 DECLINATION= 33.69 INCLINATION= 48.13

ALPHA= 6.22 DELTA= 9.84 KAPPA= 61.23

PLAT= 58.77 PLONG= -11.73 DELP = 5.33

DECLM= 8.14 STLAT= 46.05 STLONG=-122.63



77-17B, 250 OE

FISHER ON SAMPLE DIRECTIONS

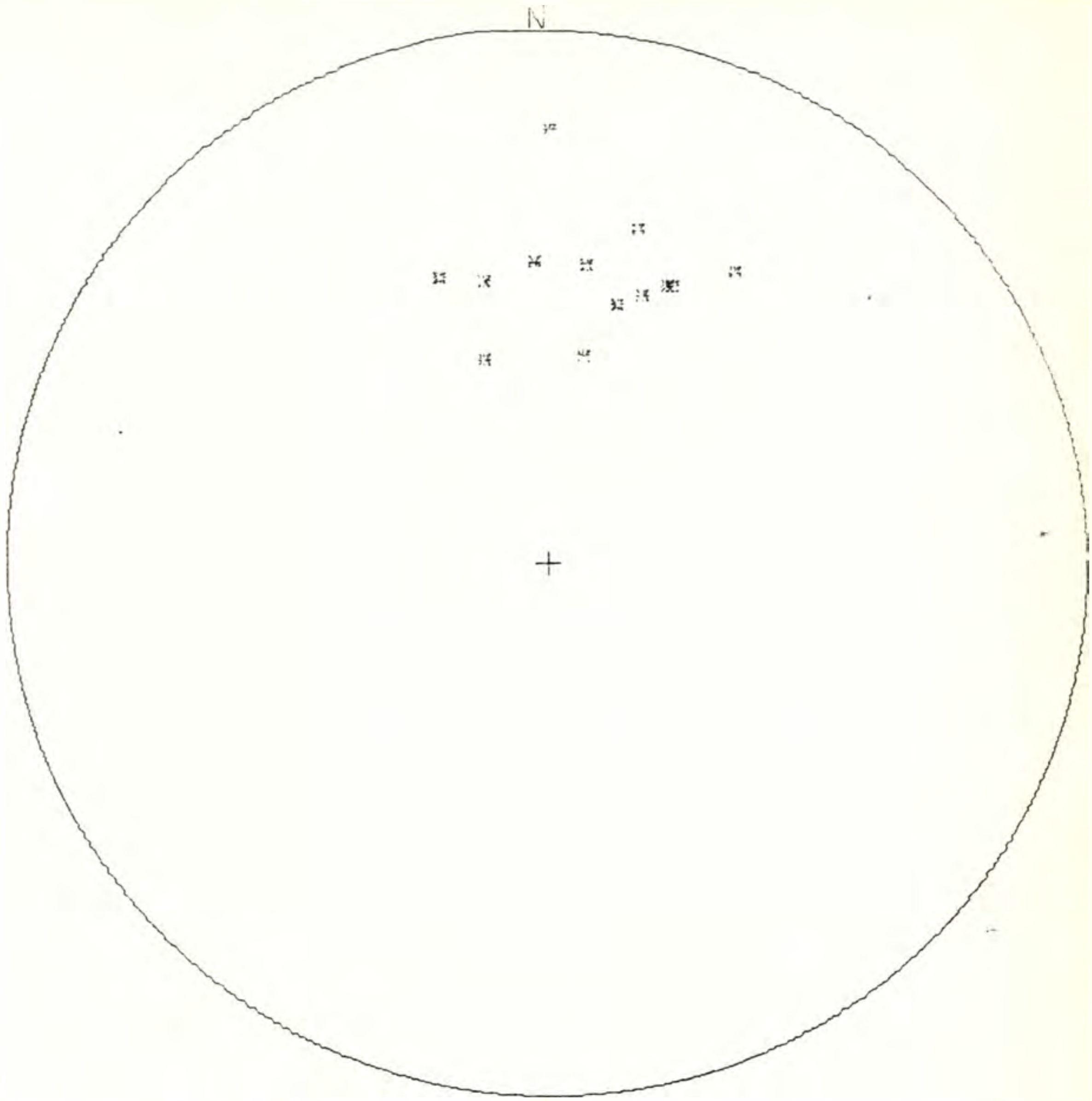
77-18B, NRM KALAMA RIVER 3

SAMPLE NUMBER	DECLINATION	INCLINATION
152	357.96	42.88
153	19.75	45.79
154	15.45	35.50
155	339.80	42.32
156	7.79	42.92
157	23.35	42.95
158	0.48	19.91
159	9.91	57.60
160	32.72	35.48
161	24.48	42.43
162	347.71	44.91
163	343.14	57.38
164	15.17	48.31

R= 12.57270 DECLINATION= 8.11 INCLINATION= 44.09

ALPHA= 7.96 DELTA= 14.73 KAPPA= 28.08

SITE LATITUDE= 46.03 SITE LONGITUDE=-122.63



77-18B. NRM KALAMA RIVER 3

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-18B, 200 OE

DIP AZIMUTH = 167.0   DIP ANGLE = 22.0

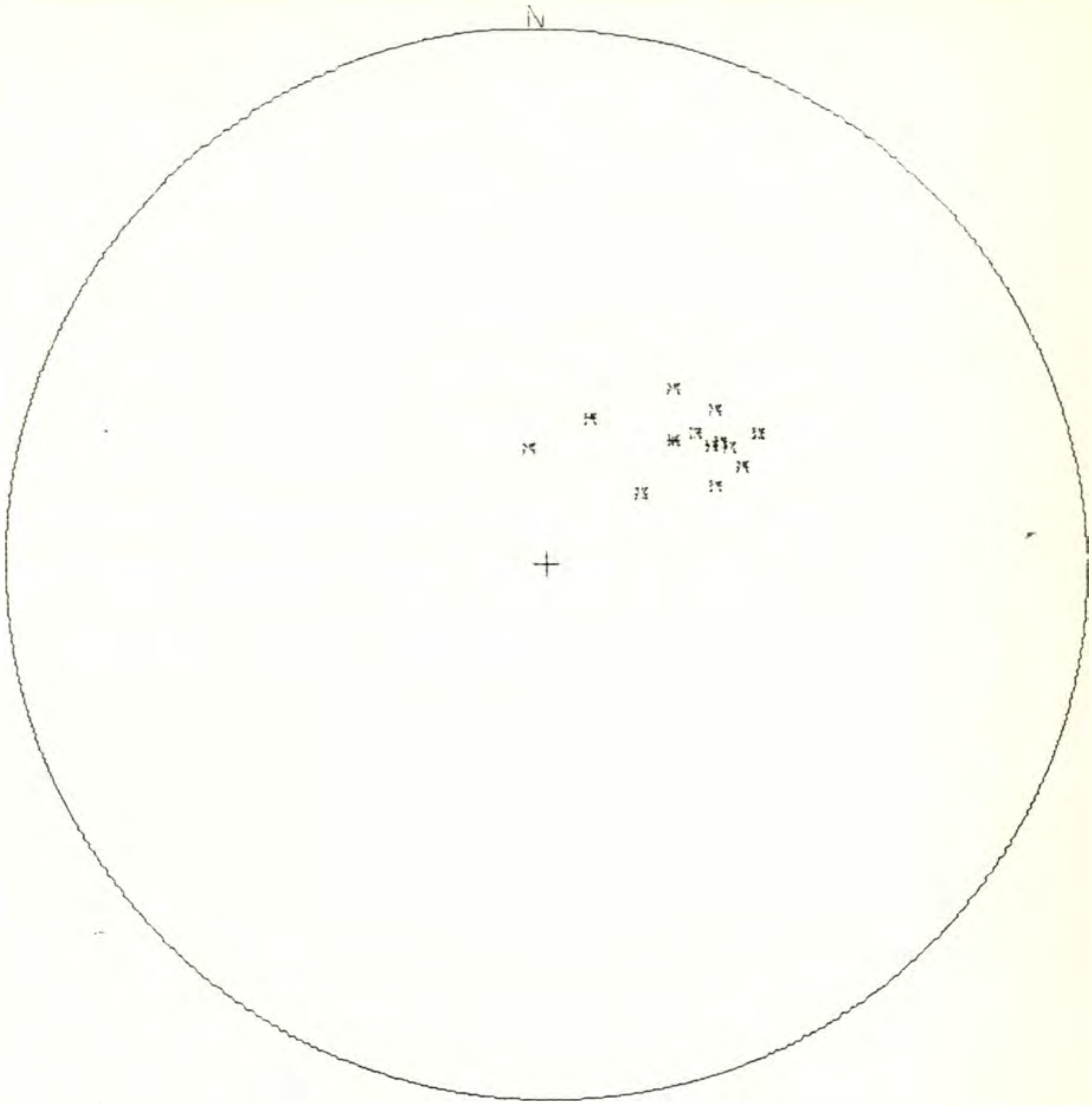
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
152	21.83	47.54	45.38	63.08
153	33.80	45.02	57.38	56.84
154	28.17	40.83	47.38	55.04
155	25.72	45.31	48.14	59.85
156	30.04	45.92	53.92	58.93
157	38.06	46.65	63.56	56.70
158	19.32	39.86	35.64	56.85
159	17.83	56.81	53.44	72.18
160	37.60	40.72	58.00	51.73
161	31.56	44.84	54.68	57.46
162	3.60	46.43	17.00	66.81
163	349.26	50.37	351.75	72.33
164	34.63	51.24	64.91	61.77

R= 12.79698   DECLINATION= 48.27   INCLINATION= 61.78

ALPHA= 5.44   DELTA= 10.14   KAPPA= 59.11

PLAT= 55.97   PLONG= -45.30   DELP = 6.51

DECLM= 8.41   STLAT= 46.03   STLONG=-122.63



77-18B. 200 OE

FISHER ON SAMPLE DIRECTIONS

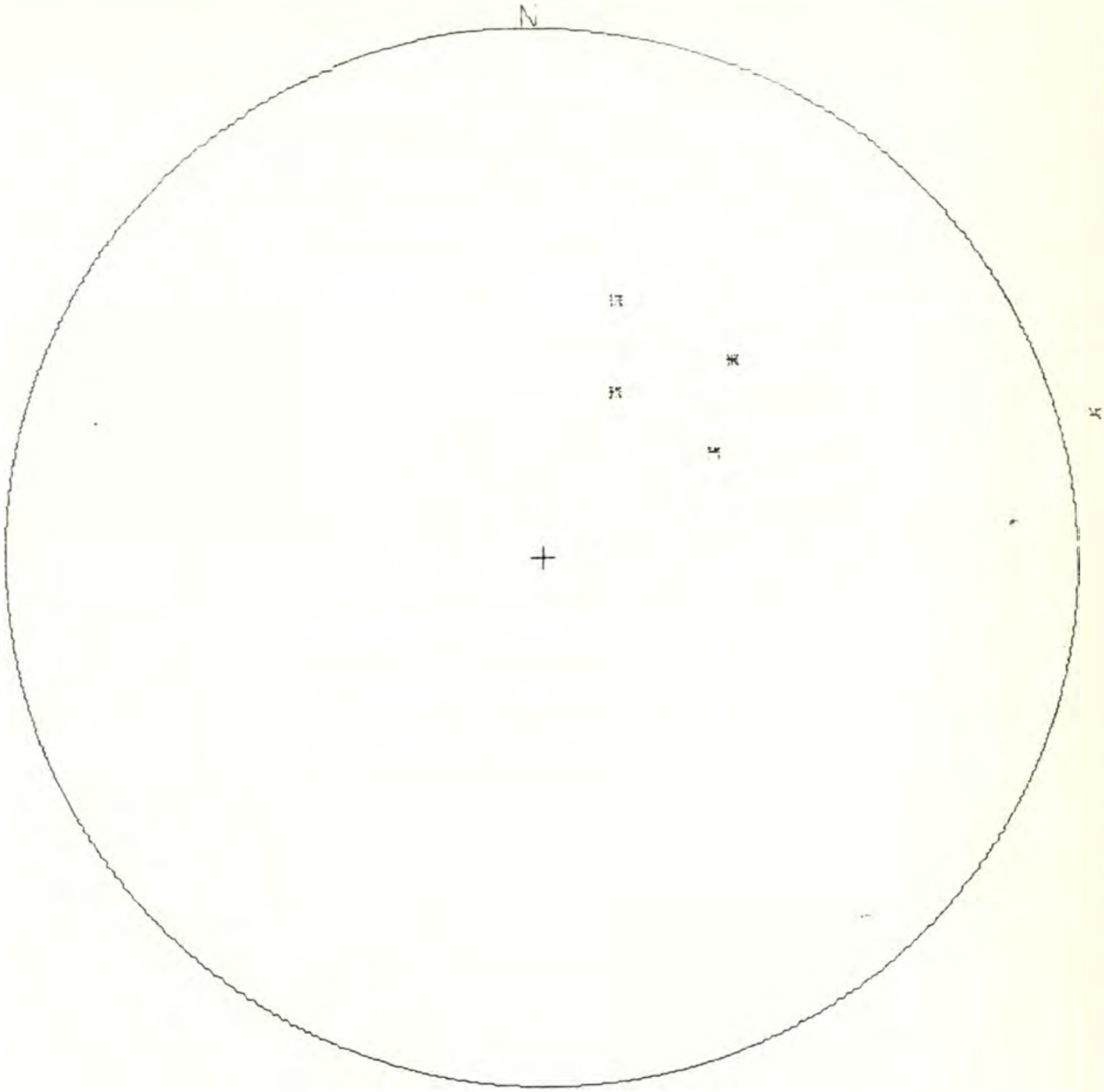
77-19B, NRM KALAMA RIVER 4

SAMPLE NUMBER	DECLINATION	INCLINATION
165	43.79	47.12
166	16.13	48.04
167	23.88	61.97
168	58.79	59.07
169	75.68	-8.34

R= 4.33354 DECLINATION= 47.27 INCLINATION= 45.14

ALPHA= 34.05 DELTA= 29.92 KAPPA= 6.00

SITE LATITUDE= 46.03 SITE LONGITUDE=-122.63



77-19B. NRM KALAMA RIVER 4

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-19B, 200 OE

DIP AZIMUTH = 180.0   DIP ANGLE = 16.0

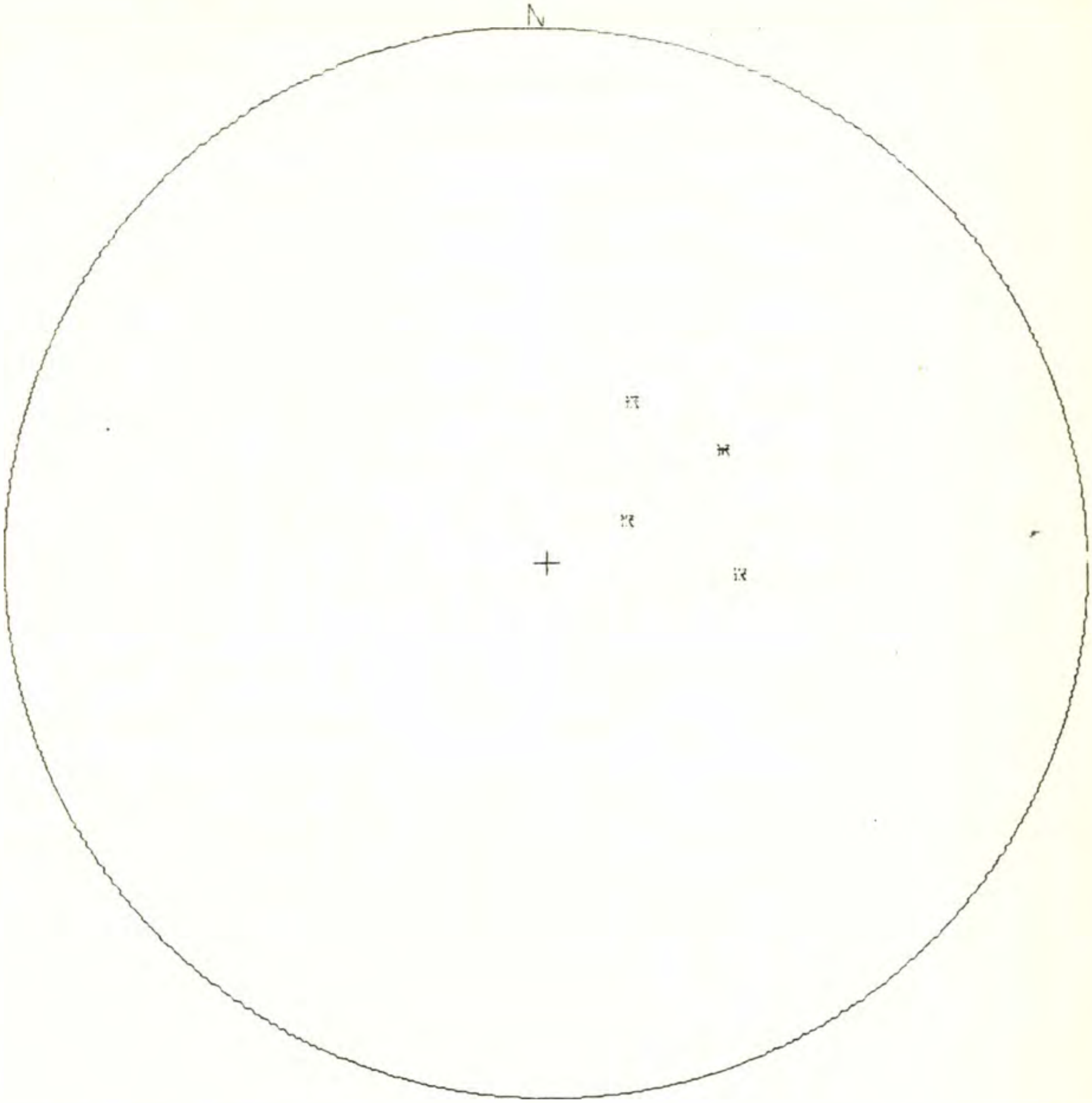
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
165	41.13	47.30	57.11	57.91
166	18.55	47.29	27.44	62.08
167	28.83	64.63	61.59	76.41
168	66.54	57.72	93.35	60.61

R= 3.90375   DECLINATION= 59.91   INCLINATION= 66.29

ALPHA= 16.72   DELTA= 12.59   KAPPA= 31.17

PLAT= 50.39   PLONG= -59.03   DELP = 22.51

DECLM= 27.44   STLAT= 46.03   STLONG=-122.63



77-19B. 200 OE

FISHER ON SAMPLE DIRECTIONS

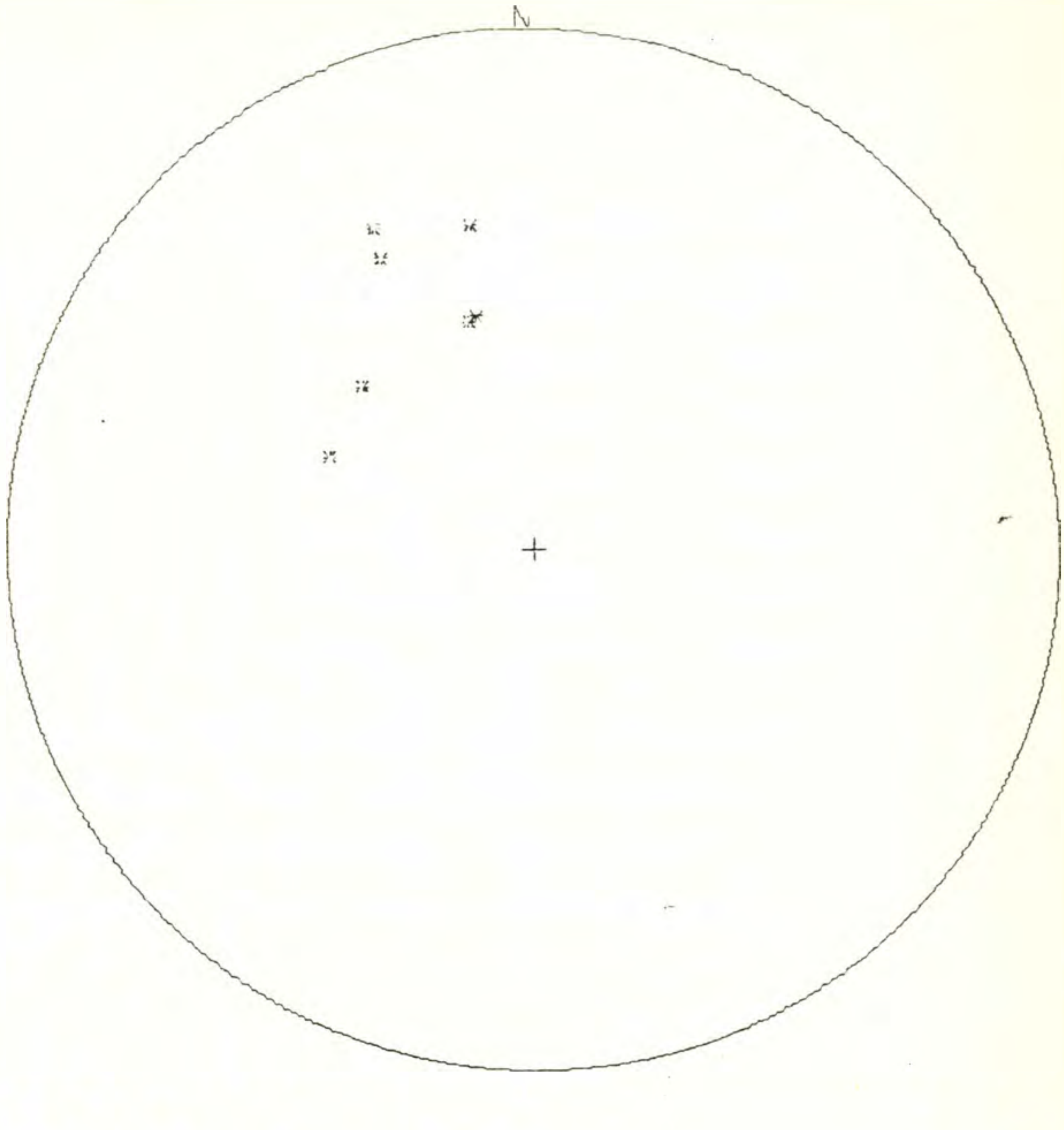
77-20B, NRM KALAMA RIVER 5

SAMPLE NUMBER	DECLINATION	INCLINATION
170	346.84	51.92
171	334.07	32.08
172	294.82	55.14
173	349.67	36.81
174	314.52	52.98
175	344.72	52.58
176	333.03	37.30

R= 6.76388 DECLINATION= 332.66 INCLINATION= 46.87

ALPHA= 12.21 DELTA= 14.92 KAPPA= 25.41

SITE LATITUDE= 46.03 SITE LONGITUDE=-122.68



77-20B. NRM KALAMA RIVER 5

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-20B, 100 OE

DIP AZIMUTH = 195.0   DIP ANGLE = 32.0

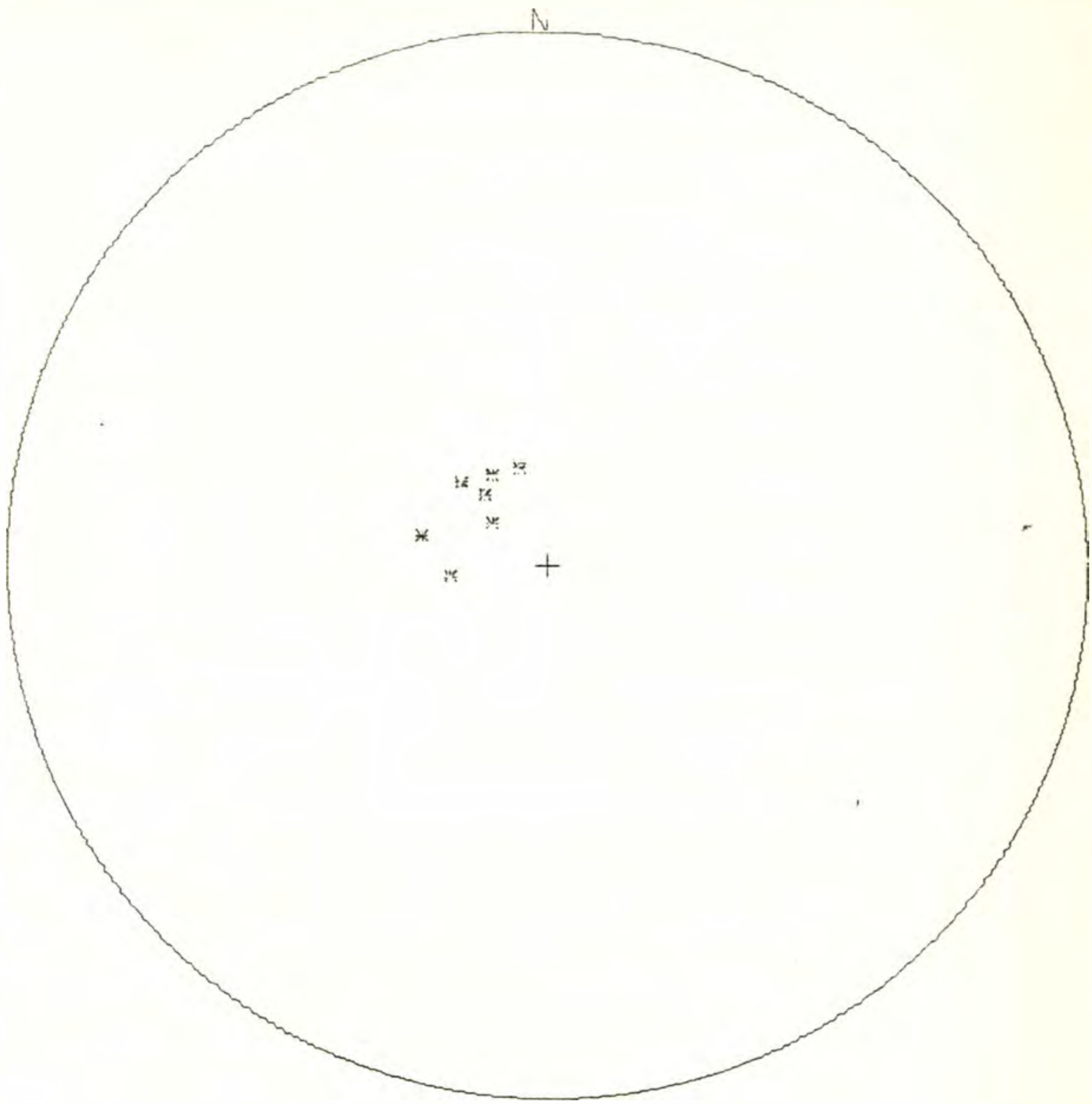
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
170	341.12	53.72	283.16	70.73
171	351.95	46.54	314.46	71.98
172	346.33	60.59	262.78	75.26
173	358.68	45.47	329.40	73.99
174	359.03	52.99	307.21	79.69
175	356.90	48.70	318.15	75.82
176	4.05	44.12	344.21	74.55

R= 6.94619   DECLINATION= 308.48   INCLINATION= 76.02

ALPHA= 5.74   DELTA= 7.11   KAPPA= 111.51

PLAT= 56.81   PLONG=-162.26   DELP = 9.77

DECLM= 10.59   STLAT= 46.03   STLONG=-122.68



77-20B. 100 OE

FISHER ON SAMPLE DIRECTIONS

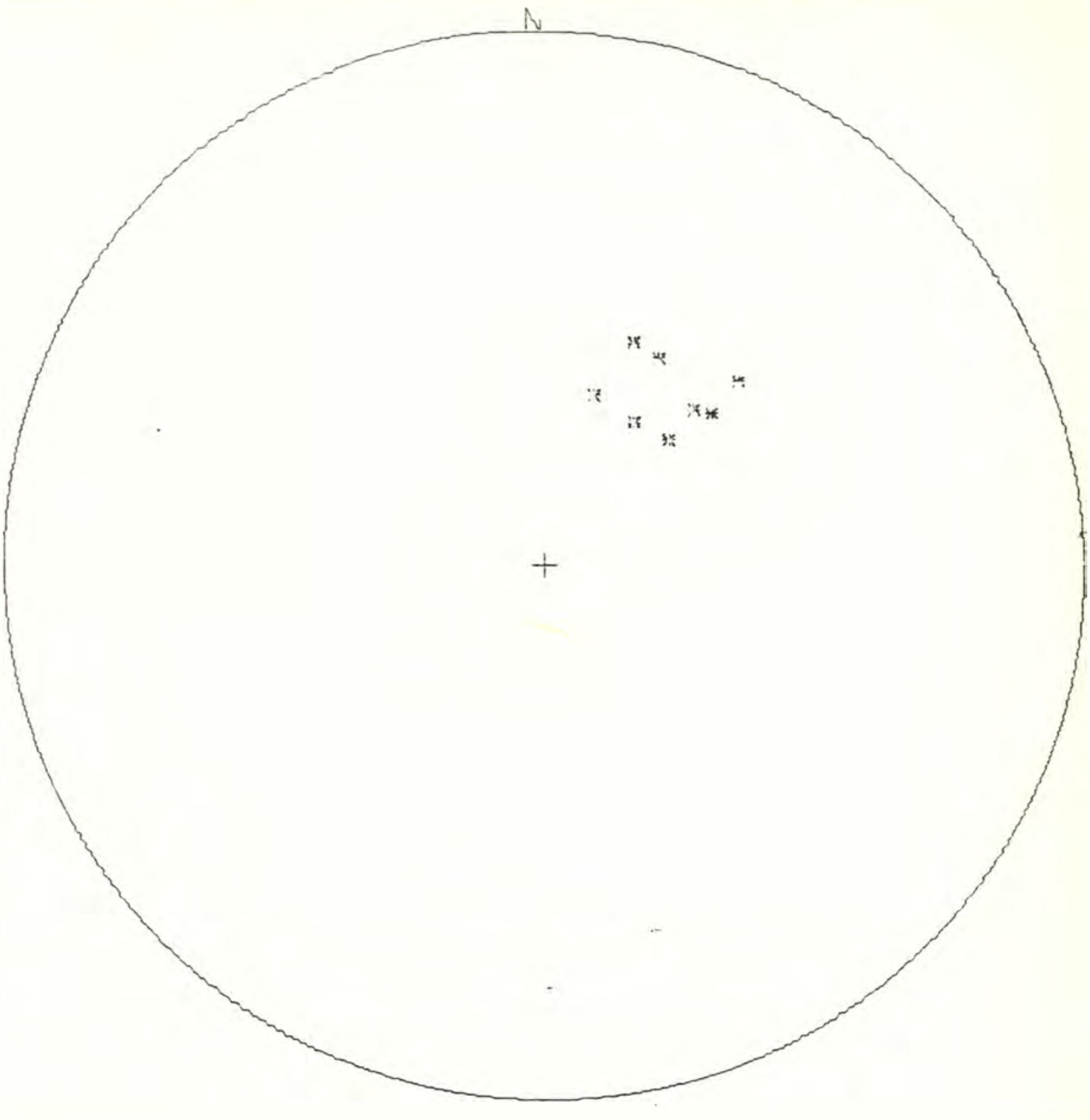
77-21B, NRM KALAMA RIVER 6

SAMPLE NUMBER	DECLINATION	INCLINATION
177	47.27	55.36
178	43.34	57.21
179	44.09	63.05
180	46.13	48.68
181	28.48	53.44
182	15.96	62.82
183	31.53	64.39
184	21.64	53.01

R= 7.92130 DECLINATION= 35.22 INCLINATION= 57.75

ALPHA= 5.91 DELTA= 8.04 KAPPA= 88.95

SITE LATITUDE= 46.02 SITE LONGITUDE=-122.73



77-21B. NRM KALAMA RIVER 6

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-21B, 200 OE

DIP AZIMUTH = 175.0 DIP ANGLE = 5.0

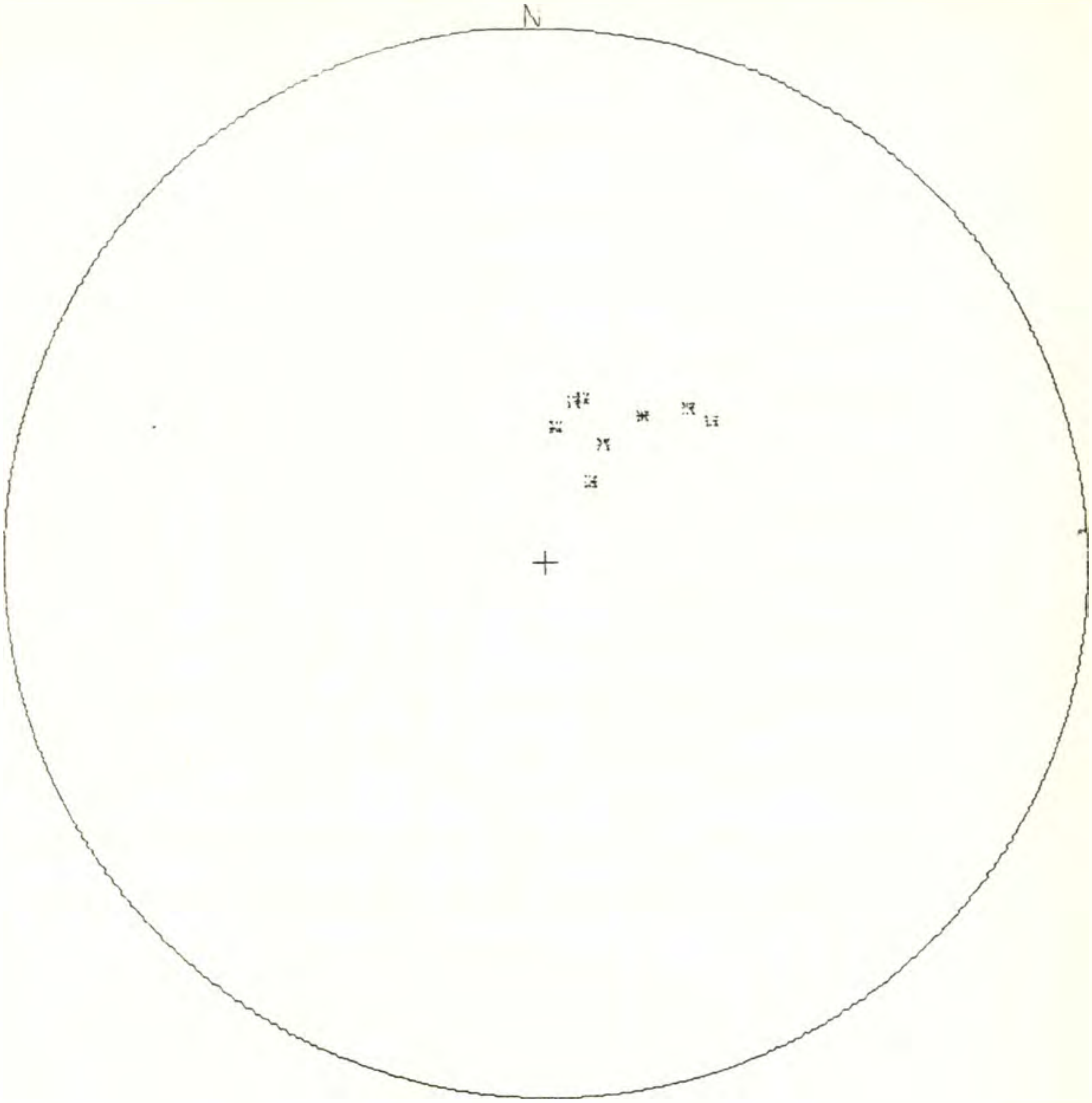
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
177	28.11	58.98	33.39	63.04
178	43.59	53.48	49.18	56.61
179	20.49	65.49	26.29	69.89
180	37.21	54.28	42.45	57.83
181	7.90	59.97	10.23	64.82
182	3.24	64.20	5.09	69.14
183	20.40	71.64	28.94	76.00
184	10.47	59.41	13.17	64.20

R= 7.90696 DECLINATION= 27.79 INCLINATION= 65.97

ALPHA= 6.43 DELTA= 8.75 KAPPA= 75.24

PLAT= 71.07 PLONG= -49.69 DELP = 8.58

DECLM= 10.50 STLAT= 46.02 STLONG=-122.73



77-21B. 200 OE

FISHER ON SAMPLE DIRECTIONS

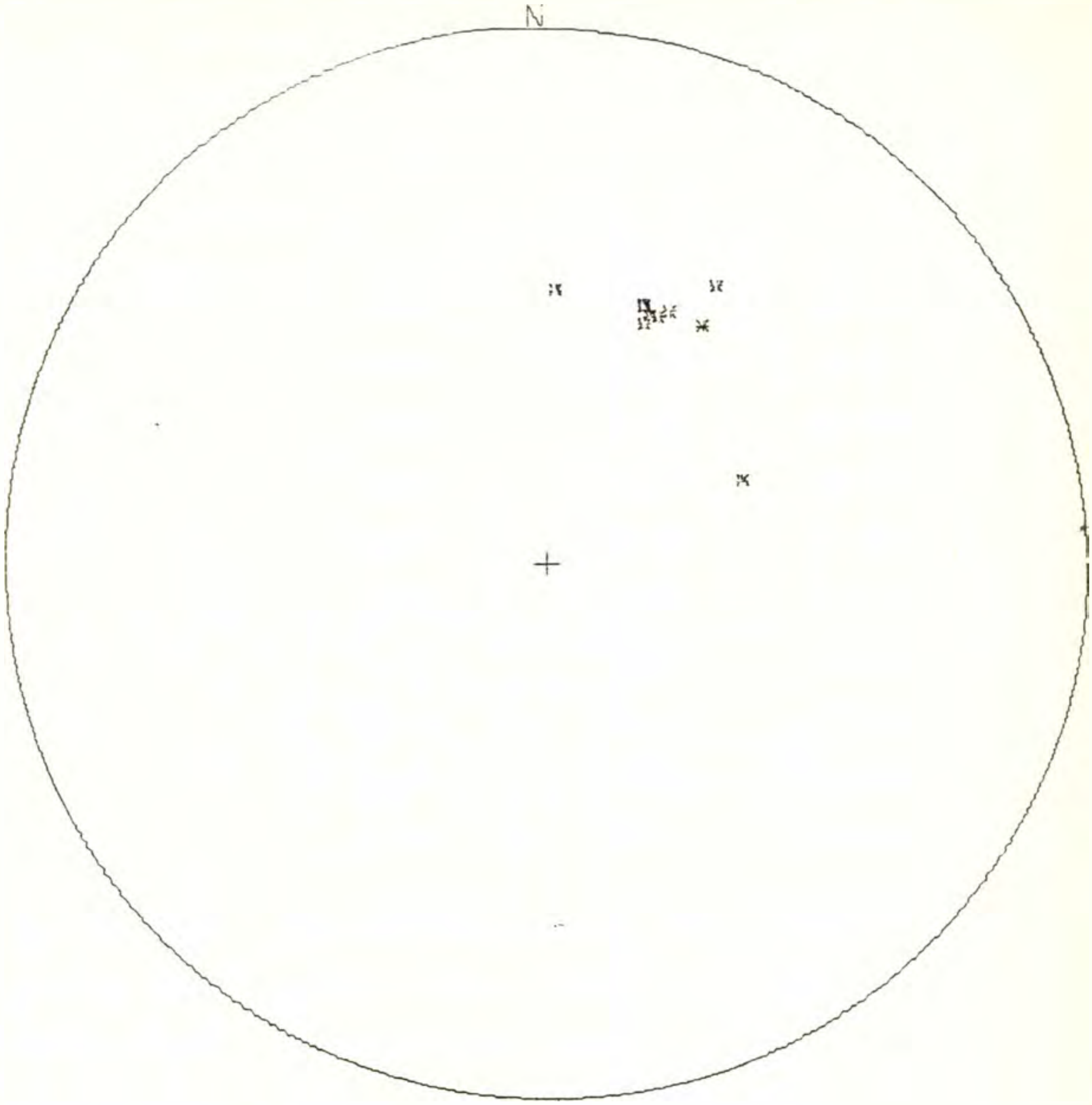
77-22B, NRM KALAMA RIVER 7

SAMPLE NUMBER	DECLINATION	INCLINATION
185	33.03	45.95
186	25.94	46.43
187	20.76	47.24
188	20.43	46.93
189	31.26	39.12
190	22.07	49.85
191	2.18	47.68
192	24.38	47.85
193	66.95	57.75
194	22.60	48.32

R= 9.83480 DECLINATION= 26.02 INCLINATION= 48.60

ALPHA= 6.60 DELTA= 10.43 KAPPA= 54.48

SITE LATITUDE= 46.03 SITE LONGITUDE=-122.78



77-22B. NRM KALAMA RIVER 7

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-228, 150 OE

DIP AZIMUTH = 125.0   DIP ANGLE = 11.0

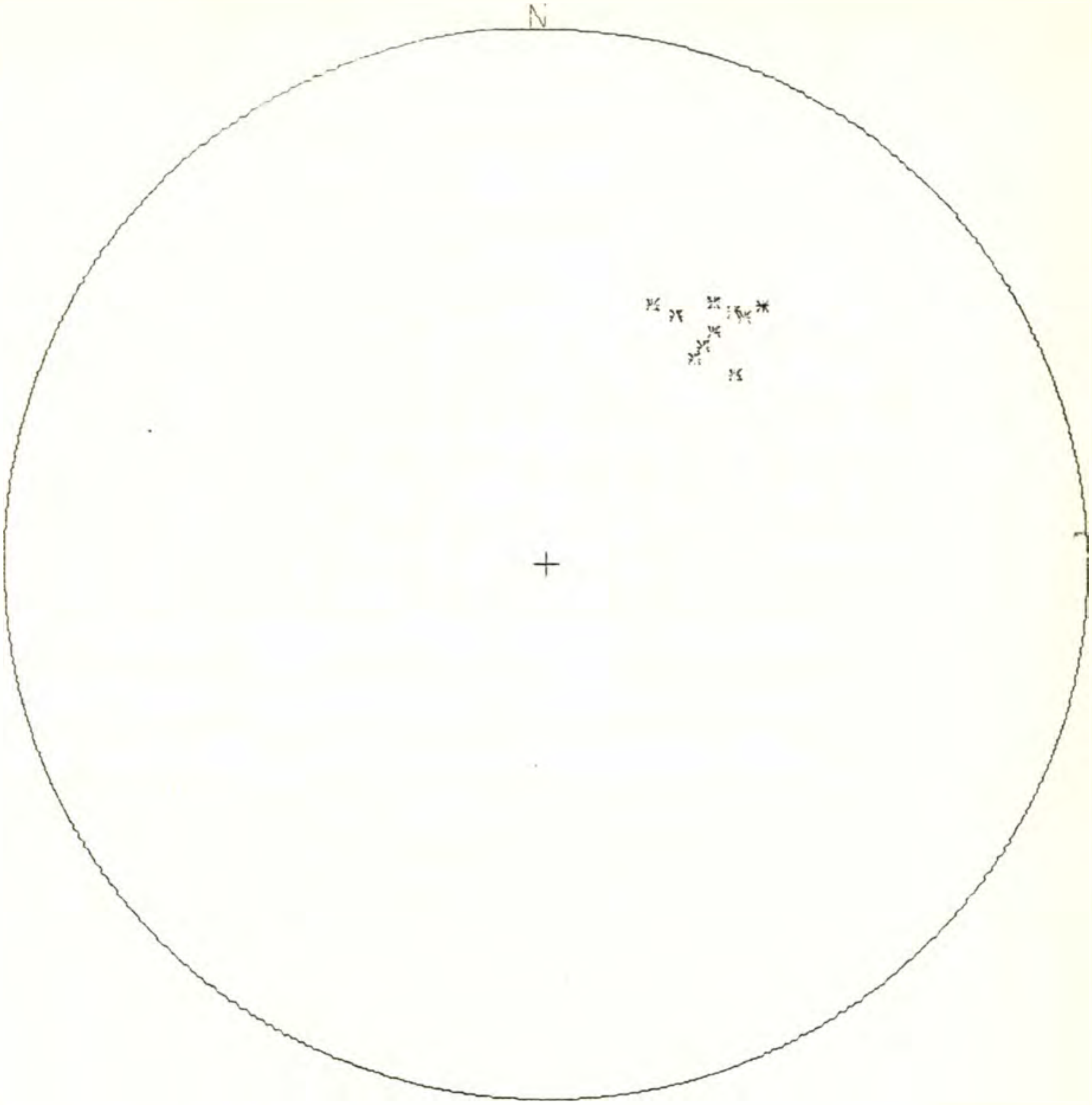
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
185	31.34	37.33	39.75	37.23
186	27.08	40.30	36.54	40.92
187	24.53	44.65	35.59	45.60
188	23.03	40.16	32.51	41.55
189	29.32	40.45	38.77	40.63
190	22.34	49.79	35.62	50.95
191	11.82	43.21	22.30	46.62
192	23.48	47.33	35.64	48.38
193	32.07	49.36	44.78	48.70
194	16.71	44.04	27.59	46.50

R= 9.94698   DECLINATION= 34.98   INCLINATION= 44.86

ALPHA= 3.72   DELTA= 5.90   KAPPA= 169.73

PLAT= 56.09   PLONG= -9.70   DELP = 2.97

DECLM= 4.70   STLAT= 46.03   STLONG=-122.78



77-22B. 150 OE

FISHER ON SAMPLE DIRECTIONS

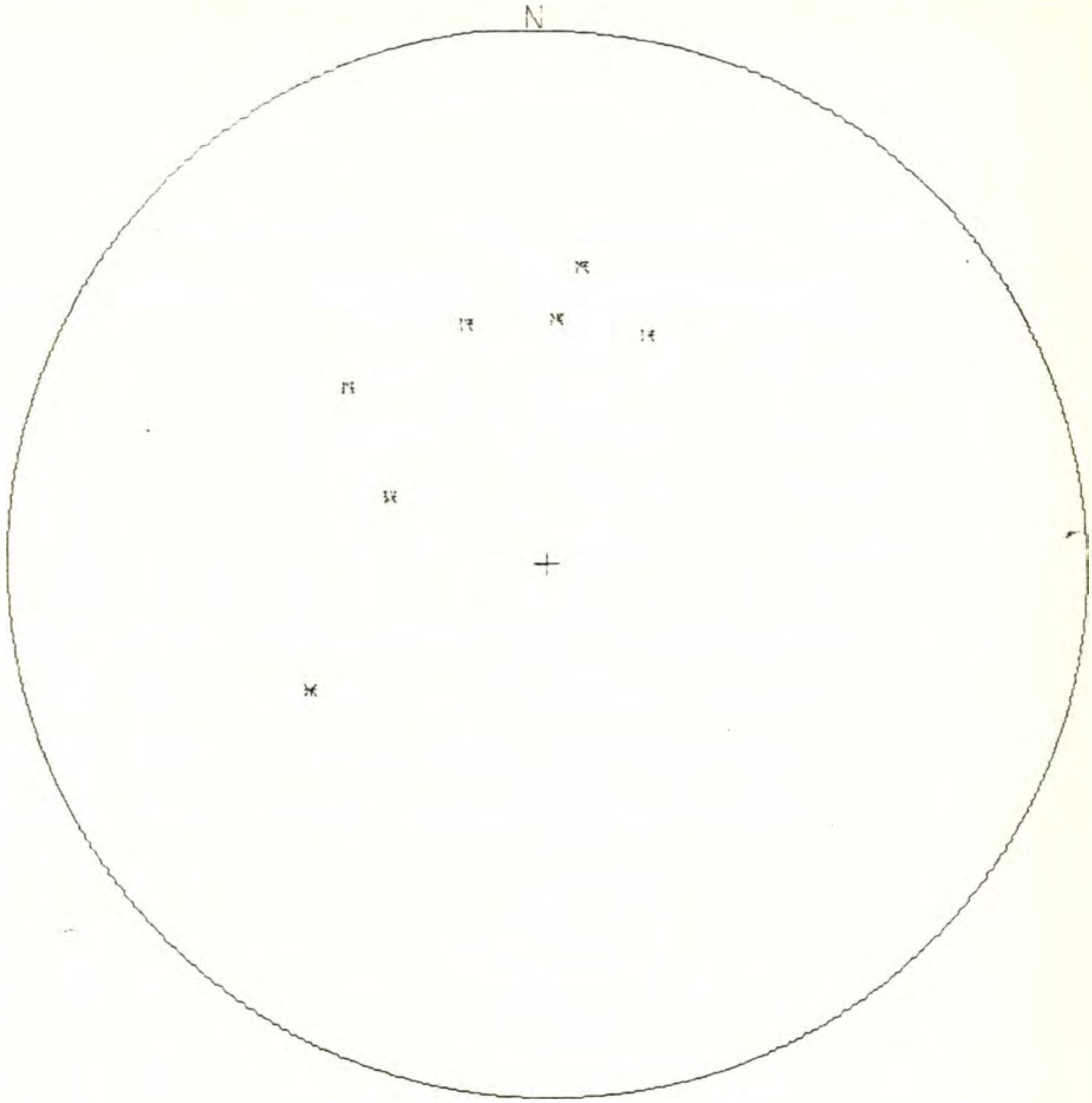
77-23B, NRM CANYON CREEK 1

SAMPLE NUMBER	DECLINATION	INCLINATION
195	241.86	48.86
196	23.71	51.27
197	6.88	43.36
198	2.82	52.22
199	342.12	50.94
200	293.55	64.39
201	312.09	49.24

R= 6.25981 DECLINATION= 335.39 INCLINATION= 60.46

ALPHA= 22.57 DELTA= 26.59 KAPPA= 8.11

SITE LATITUDE= 45.93 SITE LONGITUDE=-122.27



77-23B. NRM CANYON CREEK 1

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-23B, 150 OE

DIP AZIMUTH = 240.0 DIP ANGLE = 20.0

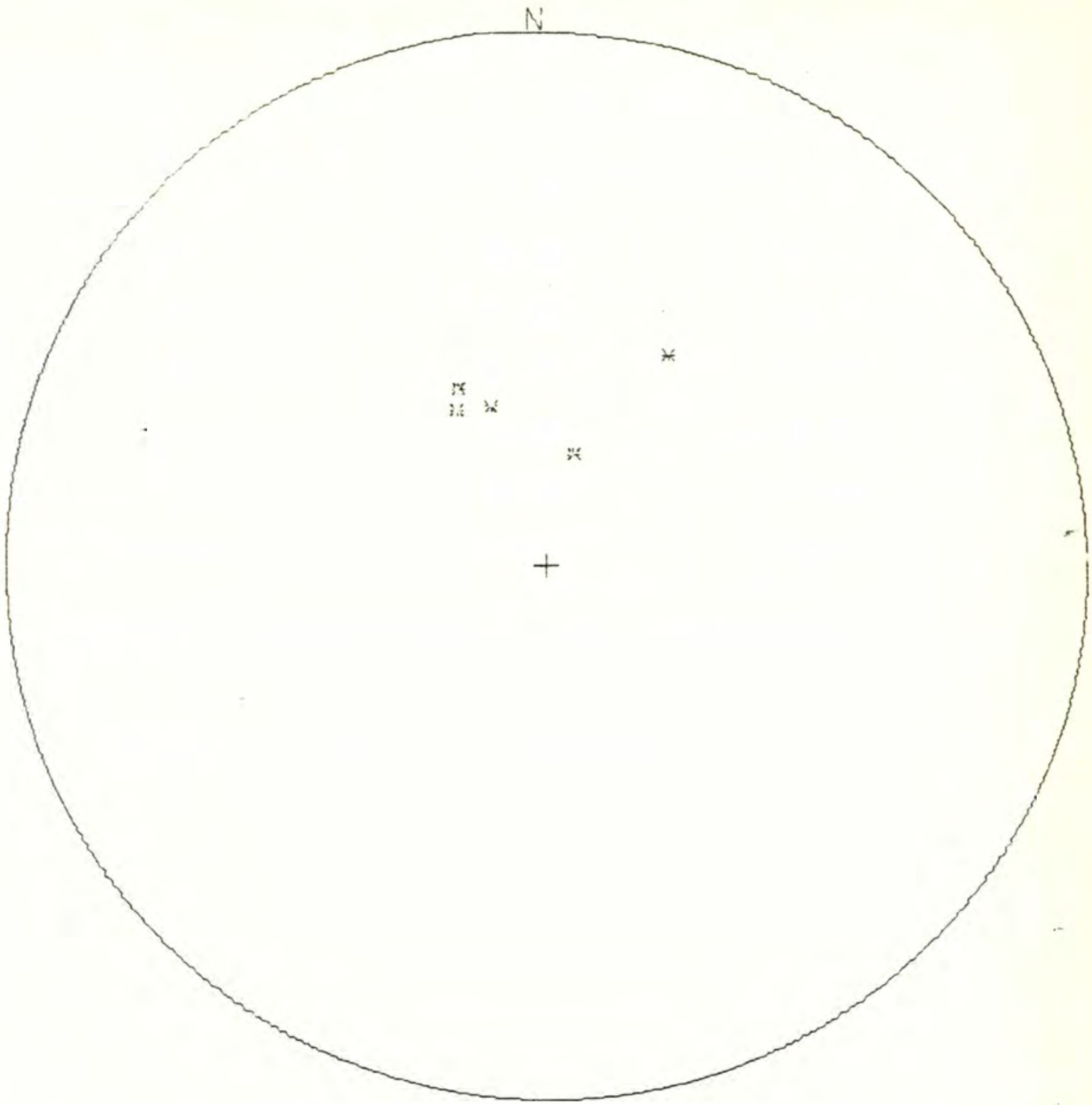
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
196	38.43	34.31	30.14	52.41
197	3.74	56.41	330.48	62.61
198	12.35	54.75	341.40	64.21
199	3.02	53.20	333.74	59.78
201	37.47	55.66	13.79	72.58

R= 4.87144 DECLINATION= 354.23 INCLINATION= 64.55

ALPHA= 13.93 DELTA= 13.02 KAPPA= 31.11

PLAT= 85.98 PLONG=-203.21 DELP = 17.93

DECLM= 22.35 STLAT= 45.93 STLONG=-122.27



77-23B. 150 ØE

FISHER ON SAMPLE DIRECTIONS

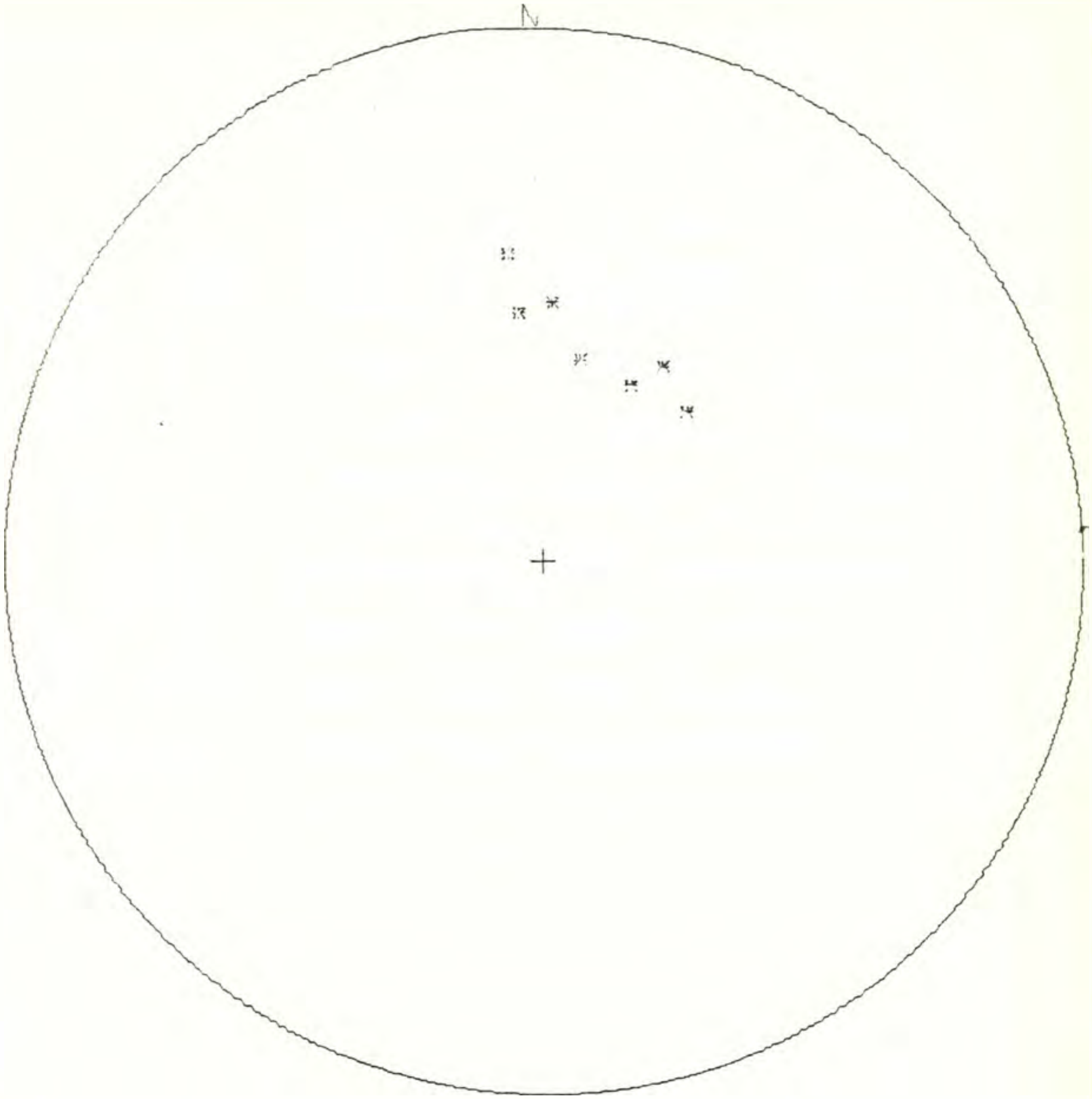
77-24B, NRM CANYON CREEK 2

SAMPLE NUMBER	DECLINATION	INCLINATION
202	2.51	49.74
203	353.93	41.61
204	354.80	51.32
205	26.65	59.82
206	43.95	58.10
207	31.54	54.82
208	10.56	58.47

R= 6.84337 DECLINATION= 12.92 INCLINATION= 54.78

ALPHA= 9.88 DELTA= 12.14 KAPPA= 38.31

SITE LATITUDE= 45.95 SITE LONGITUDE=-122.32



77-24B. NRM CANYON CREEK 2

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-24B, 200 DE

DIP AZIMUTH = 55.0 DIP ANGLE = 16.0

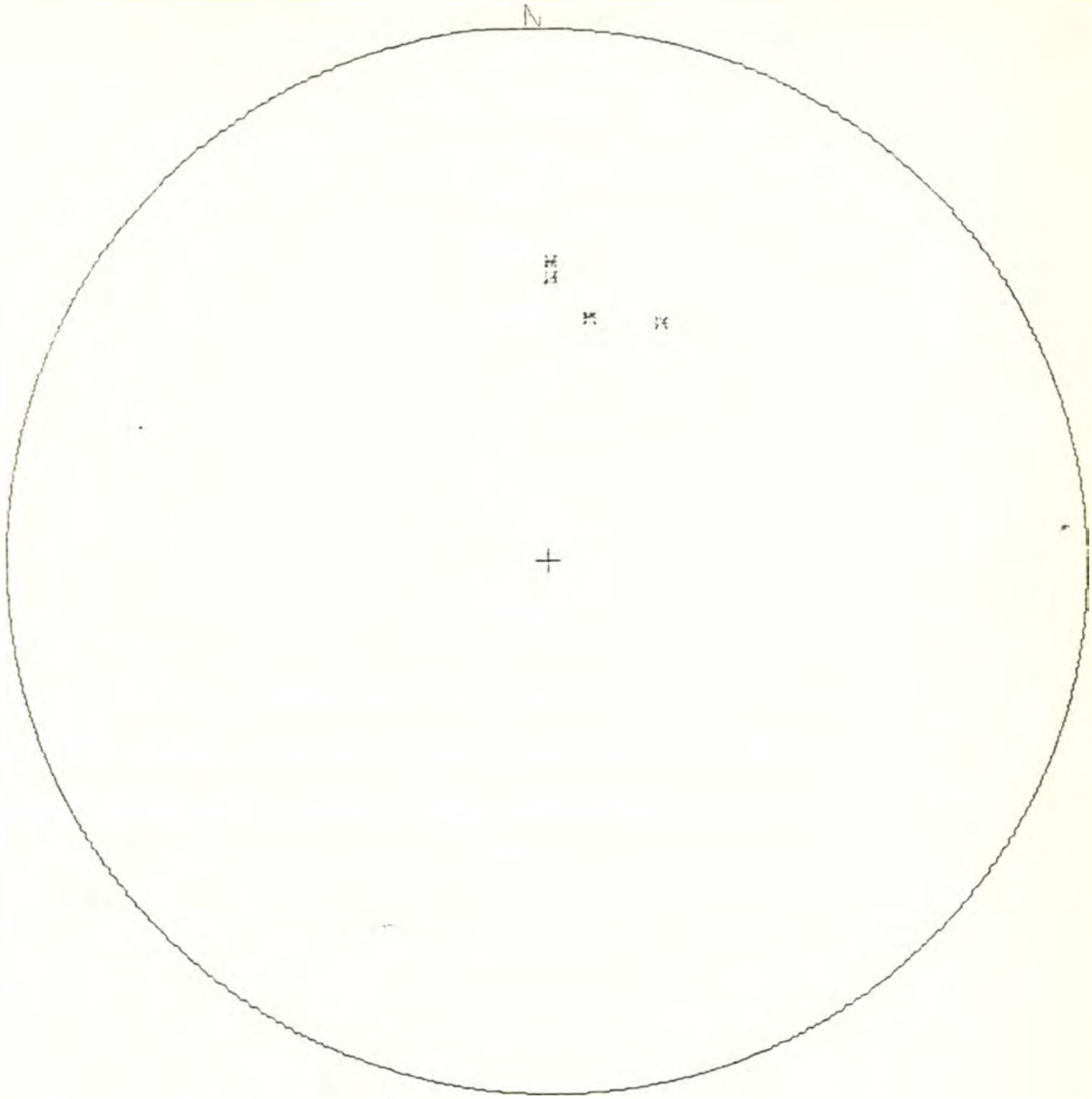
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
203	345.93	51.01	1.21	43.25
204	344.36	53.52	1.24	45.94
205	11.65	62.23	25.68	49.21
208	350.26	61.14	10.19	51.73

R= 3.96633 DECLINATION= 9.17 INCLINATION= 47.97

ALPHA= 9.79 DELTA= 7.44 KAPPA= 89.11

PLAT= 71.60 PLONG= 31.49 DELP = 8.35

DECLM= 12.78 STLAT= 45.95 STLONG=-122.32



77-24B. 200 ØE

FISHER ON SAMPLE DIRECTIONS

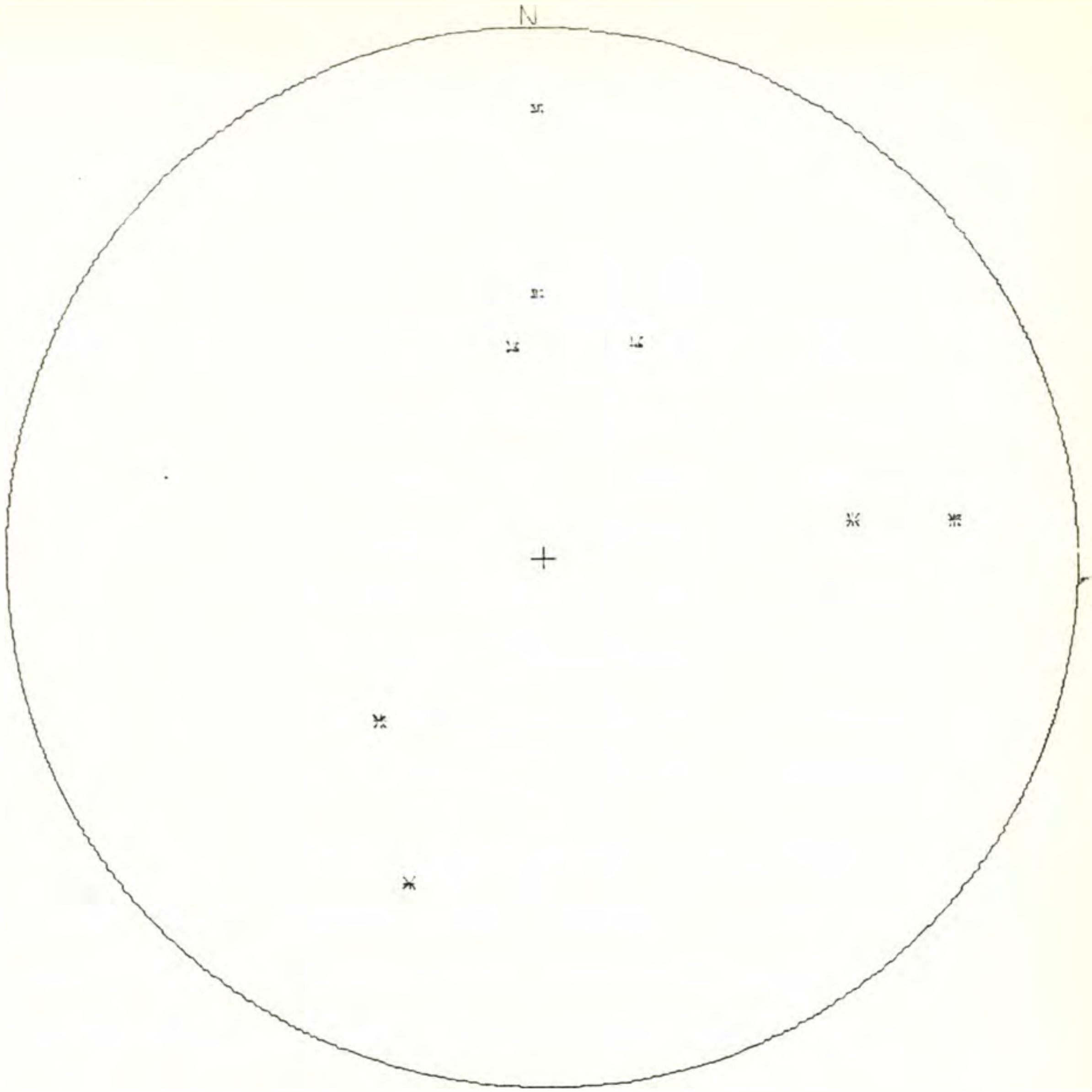
77-25B, NRM CANYON CREEK 3

SAMPLE NUMBER	DECLINATION	INCLINATION
209	202.51	-34.13
210	23.61	53.60
211	83.44	41.14
212	85.17	23.59
213	225.01	-54.65
214	359.38	48.73
215	359.90	16.30
216	352.61	57.02

R= 3.10140 DECLINATION= 32.88 INCLINATION= 49.47

ALPHA= 81.00 DELTA= 67.19 KAPPA= 1.43

SITE LATITUDE= 45.93 SITE LONGITUDE=-122.27



77-25B. NRM CANYON CREEK 3

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-25B, 200 OE

DIP AZIMUTH = 45.0 DIP ANGLE = 20.0

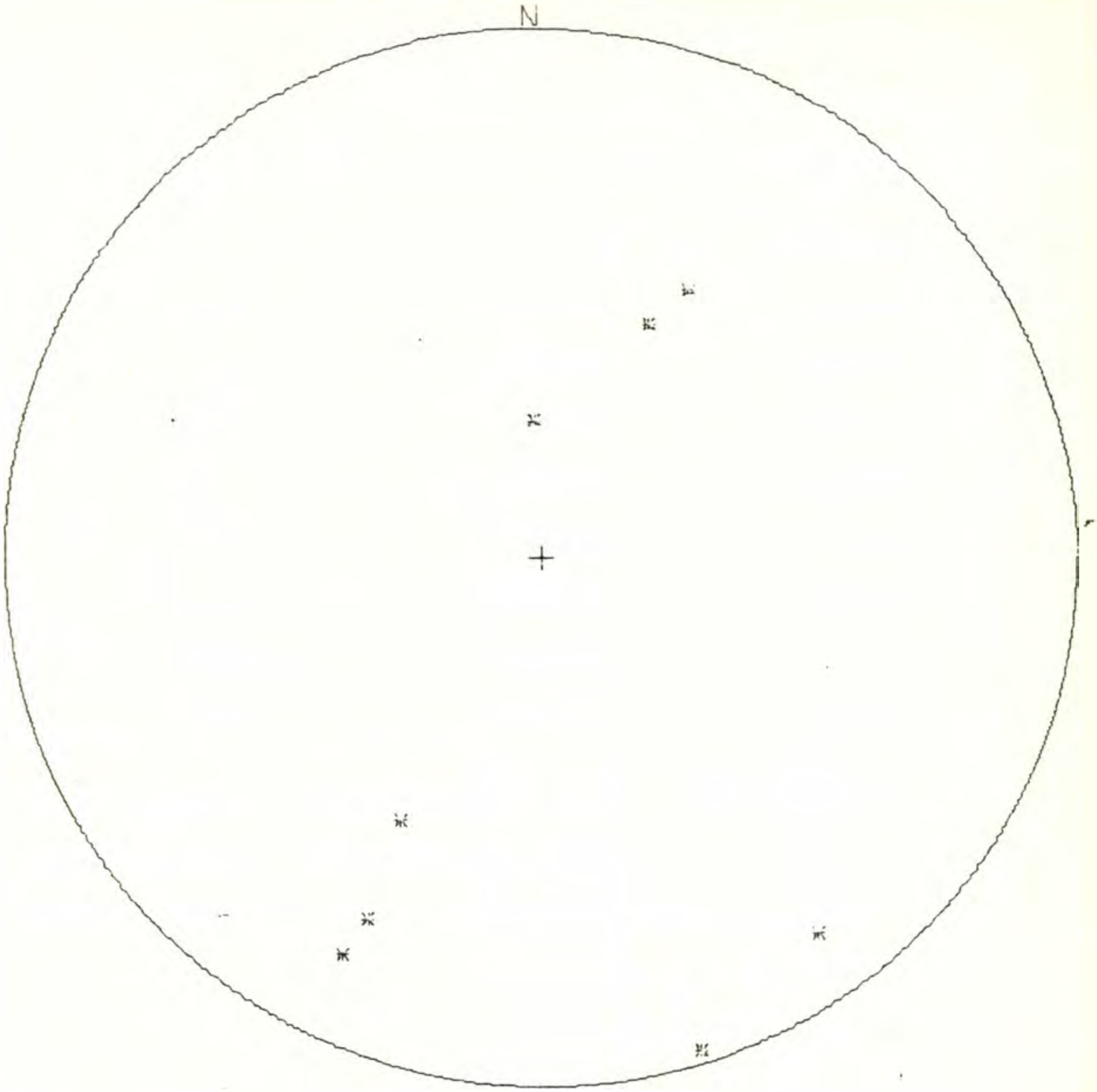
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
209	203.17	-36.25	206.68	-17.43
210	19.84	60.56	28.73	41.77
211	162.02	-6.73	162.68	2.53
212	200.48	-43.91	205.69	-25.31
213	198.65	-61.92	208.34	-43.22
214	296.99	73.69	357.72	68.68
215	148.33	9.58	144.28	13.54
216	9.30	67.71	24.93	49.83

R= 2.75808 DECLINATION= 172.67 INCLINATION= 26.44

ALPHA= 90.87 DELTA= 69.83 KAPPA= 1.34

PLAT= -29.74 PLONG=-114.08 DELP = 53.37

DECLM= 98.49 STLAT= 45.93 STLONG=-122.27



77-25B. 200 OE

FISHER ON SAMPLE DIRECTIONS

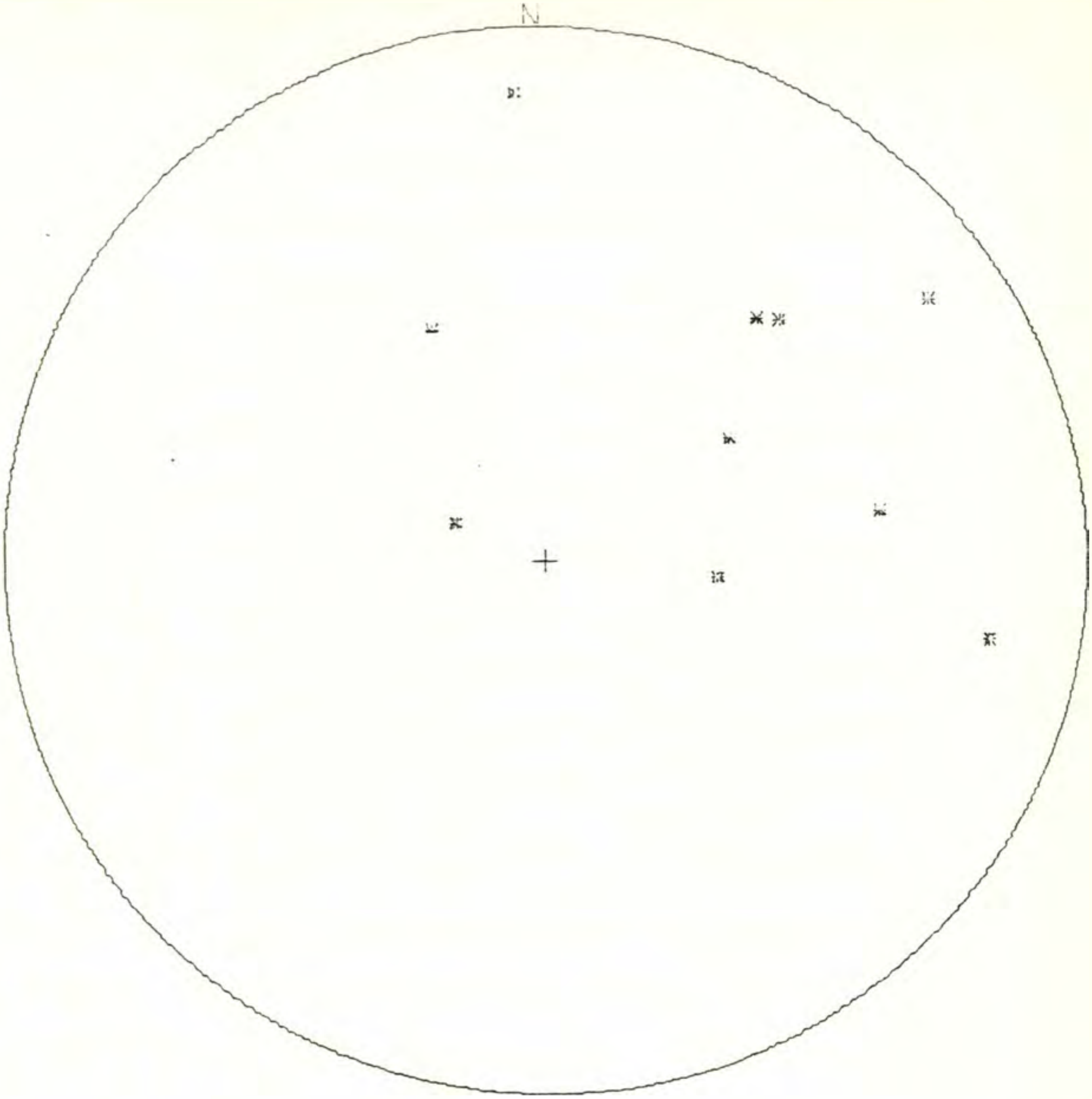
77-26B, NRM CANYON CREEK 4

SAMPLE NUMBER	DECLINATION	INCLINATION
217	41.25	39.79
218	55.71	-15.02
219	100.42	17.95
220	44.25	37.54
221	81.66	37.63
222	55.99	56.20
223	293.77	75.69
224	95.60	63.98
225	356.81	13.46
226	335.02	50.46

R= 7.71314 DECLINATION= 47.89 INCLINATION= 46.68

ALPHA= 28.01 DELTA= 39.53 KAPPA= 3.94

SITE LATITUDE= 45.94 SITE LONGITUDE=-122.30



77-26B. NRM CANYON CREEK 4

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-26B, 200 OE

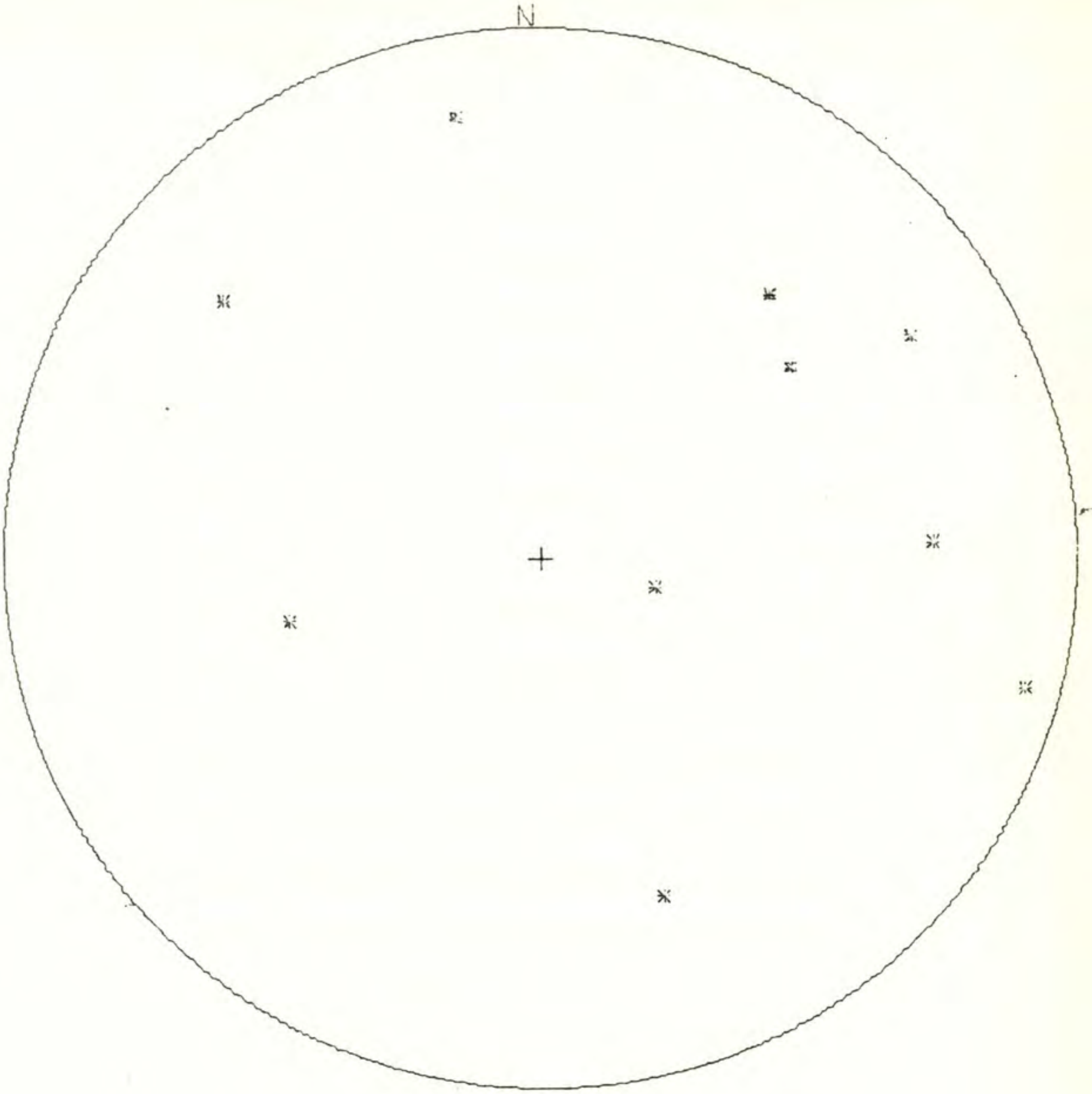
SAMPLE NUMBER	DECLINATION	INCLINATION
217	41.01	34.75
218	59.13	-20.04
219	105.44	7.29
220	52.66	40.69
221	87.91	27.55
222	104.74	72.14
223	256.39	50.01
224	160.72	32.96
225	349.78	-16.64
226	309.81	24.78

R= 5.15132 DECLINATION= 57.45 INCLINATION= 48.59

ALPHA= 51.08 DELTA= 58.99 KAPPA= 1.86

PLAT= 42.84 PLONG= -32.82 DELP = 44.18

DECLM= 67.18 STLAT= 45.94 STLONG=-122.30



77-26B. 200 OE

FISHER ON SAMPLE DIRECTIONS

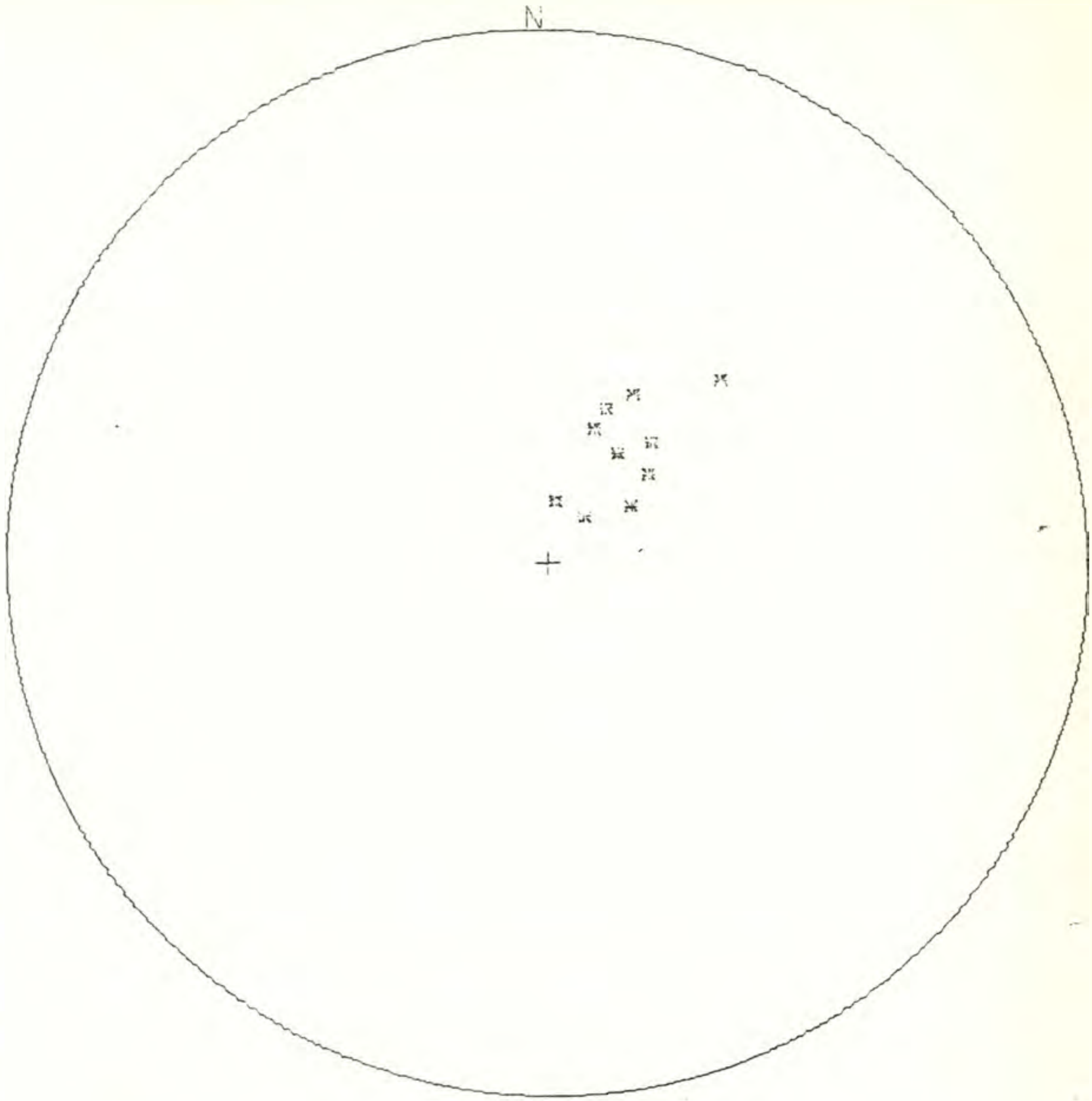
77-27B, NRM AMBOY

SAMPLE NUMBER	DECLINATION	INCLINATION
227	56.23	74.78
228	38.34	81.08
229	40.56	65.65
230	20.94	64.68
231	49.07	69.67
232	32.67	70.09
233	19.29	68.16
234	43.77	51.02
235	27.29	61.03
236	7.66	80.51

R= 9.85797 DECLINATION= 34.43 INCLINATION= 69.15

ALPHA= 6.12 DELTA= 9.67 KAPPA= 63.37

SITE LATITUDE= 45.92 SITE LONGITUDE=-122.48



77-27B, NRM AMBOY

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-27B, 150 OE

DIP AZIMUTH = 315.0   DIP ANGLE = 12.0

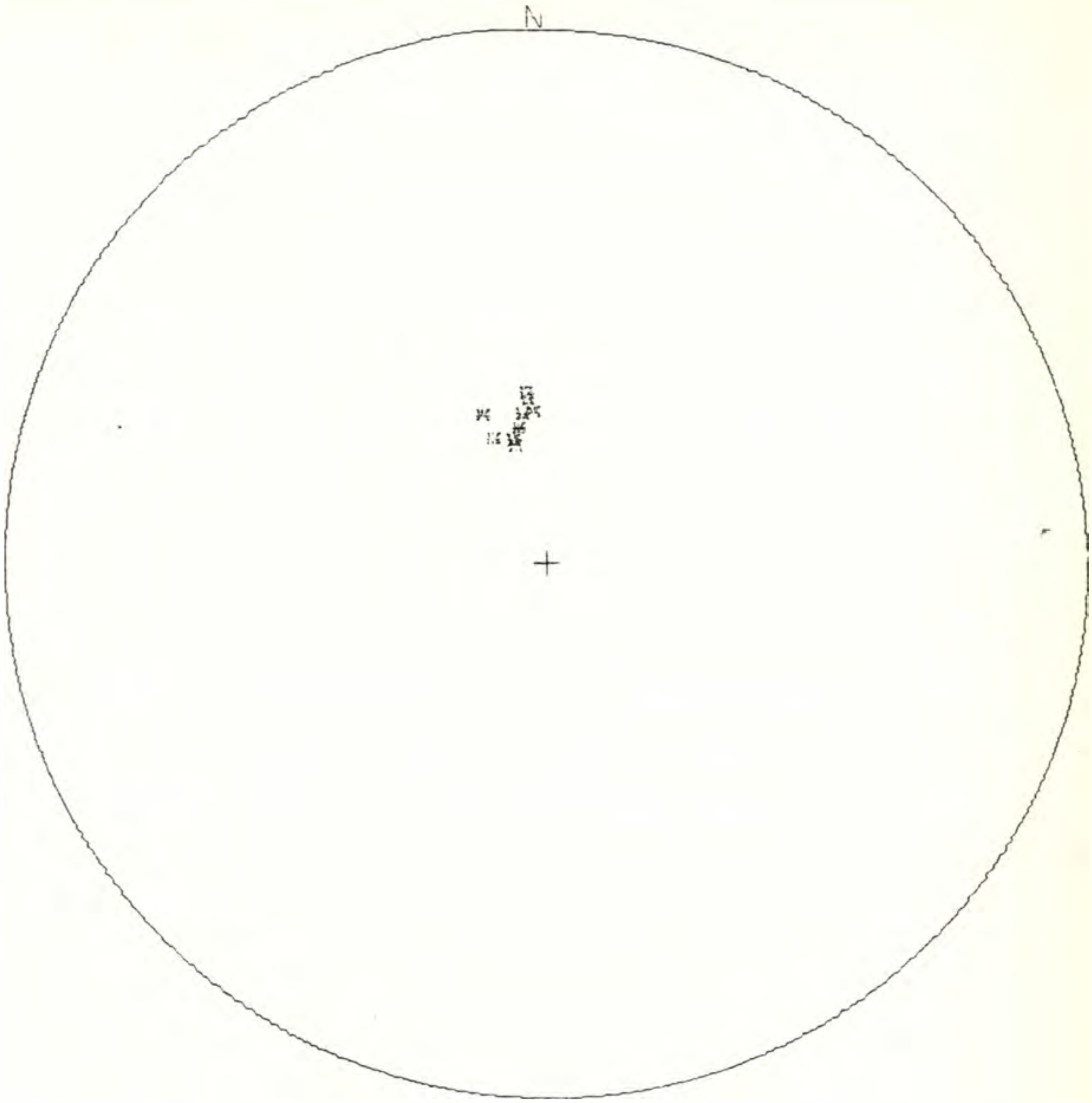
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
227	19.19	77.01	349.15	68.87
228	3.14	79.39	337.91	69.37
229	18.35	74.59	351.84	66.66
230	17.83	72.32	353.99	64.57
231	16.17	71.42	353.78	63.54
232	19.02	79.00	345.97	70.53
233	355.37	75.83	337.44	65.45
234	21.71	79.59	346.17	71.30
235	23.31	73.91	355.65	66.71

R= 8.98267   DECLINATION= 348.27   INCLINATION= 67.57

ALPHA= 2.40   DELTA= 3.56   KAPPA= 461.63

PLAT= 80.97   PLONG=-178.04   DELP = 3.34

DECLM= 4.00   STLAT= 45.92   STLONG=-122.48



77-27B. 150 0E

FISHER ON SAMPLE DIRECTIONS

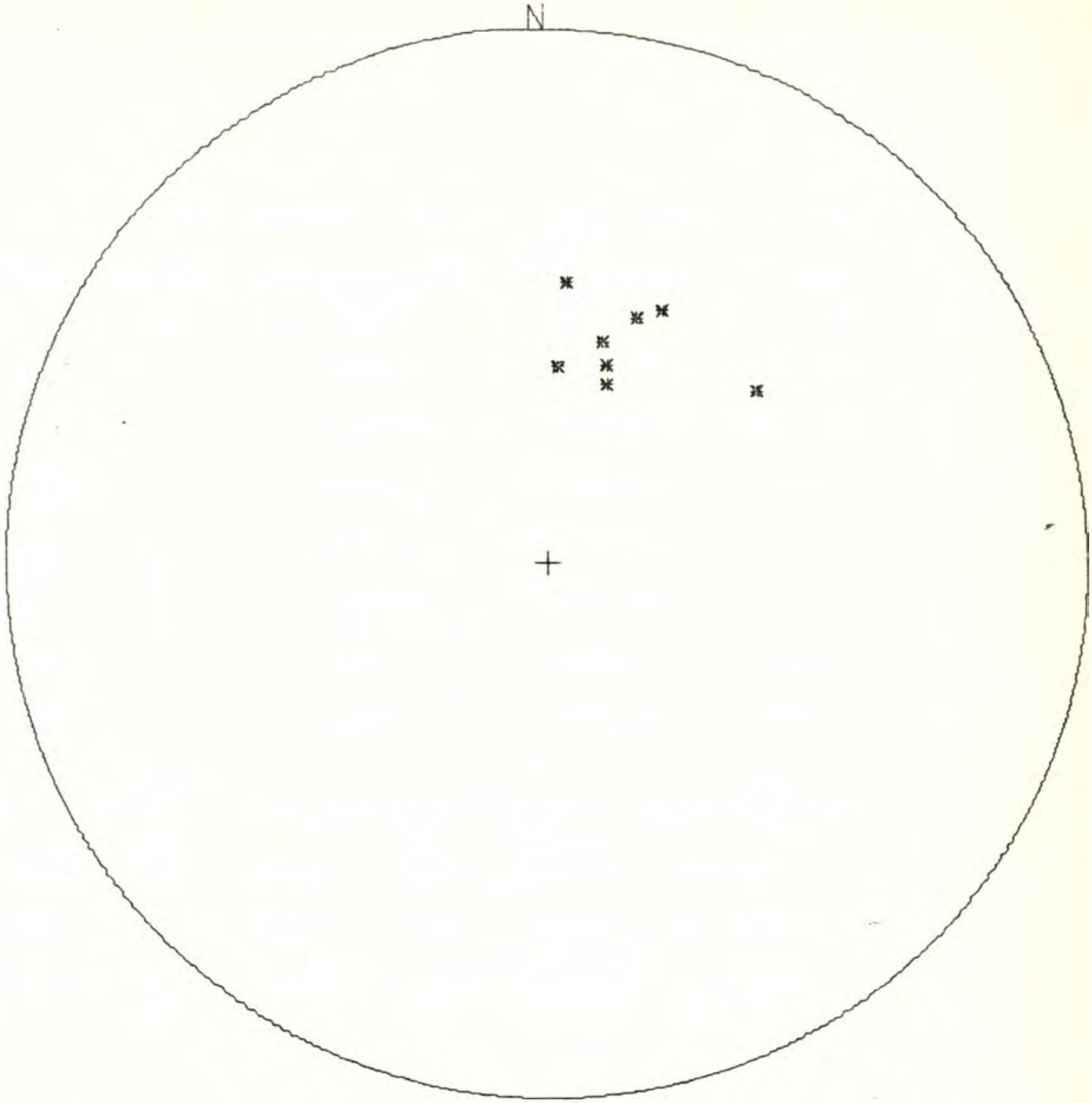
77-28B, NRM CHELATCHIE PRAIRIE

SAMPLE NUMBER	DECLINATION	INCLINATION
237	24.47	46.86
238	20.01	49.68
239	4.23	46.16
240	50.51	48.17
241	18.66	61.03
242	14.03	54.86
243	3.32	59.72
244	16.98	58.15

R= 7.87412 DECLINATION= 19.51 INCLINATION= 53.92

ALPHA= 7.49 DELTA= 10.18 KAPPA= 55.61

SITE LATITUDE= 45.77 SITE LONGITUDE=-122.42



77-28B, NRM CHELATCHIE PRAIRIE

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-28B, 150 OE

DIP AZIMUTH = 325.0   DIP ANGLE = 20.0

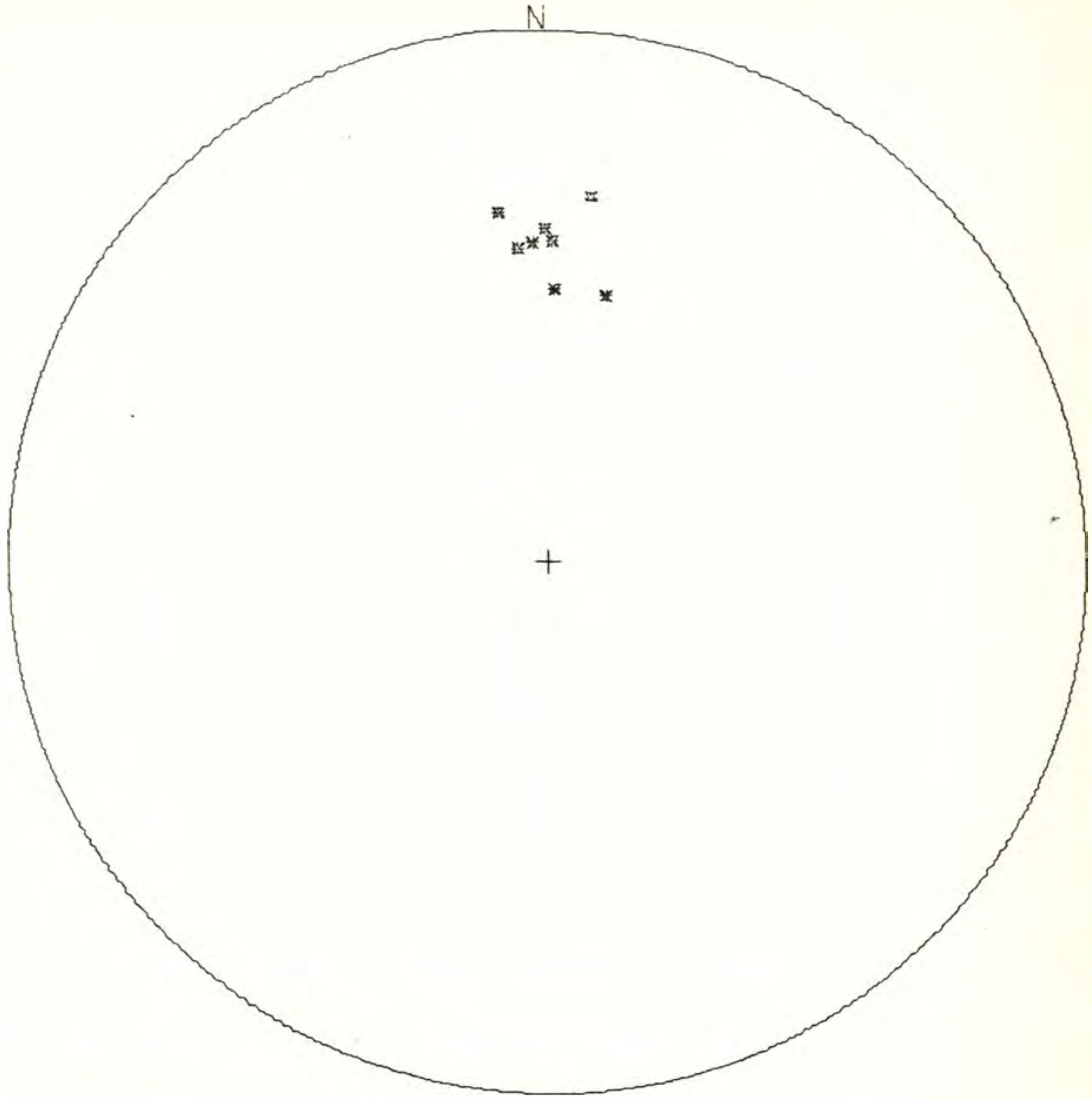
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
237	22.33	61.41	1.57	47.46
238	13.33	52.66	359.84	37.53
239	8.75	56.95	354.86	40.76
240	35.73	58.07	12.70	47.55
241	15.95	54.31	1.02	39.61
242	19.00	45.16	7.07	31.64
243	2.19	51.24	352.23	34.21
244	11.92	55.33	357.73	39.79

R= 7.93993   DECLINATION= 0.69   INCLINATION= 39.97

ALPHA= 5.15   DELTA= 7.03   KAPPA= 116.53

PLAT= 66.96   PLONG= 55.96   DELP = 3.73

DECLM= 6.20   STLAT= 45.77   STLONG=-122.42



77-28B, 150 OE

FISHER ON SAMPLE DIRECTIONS

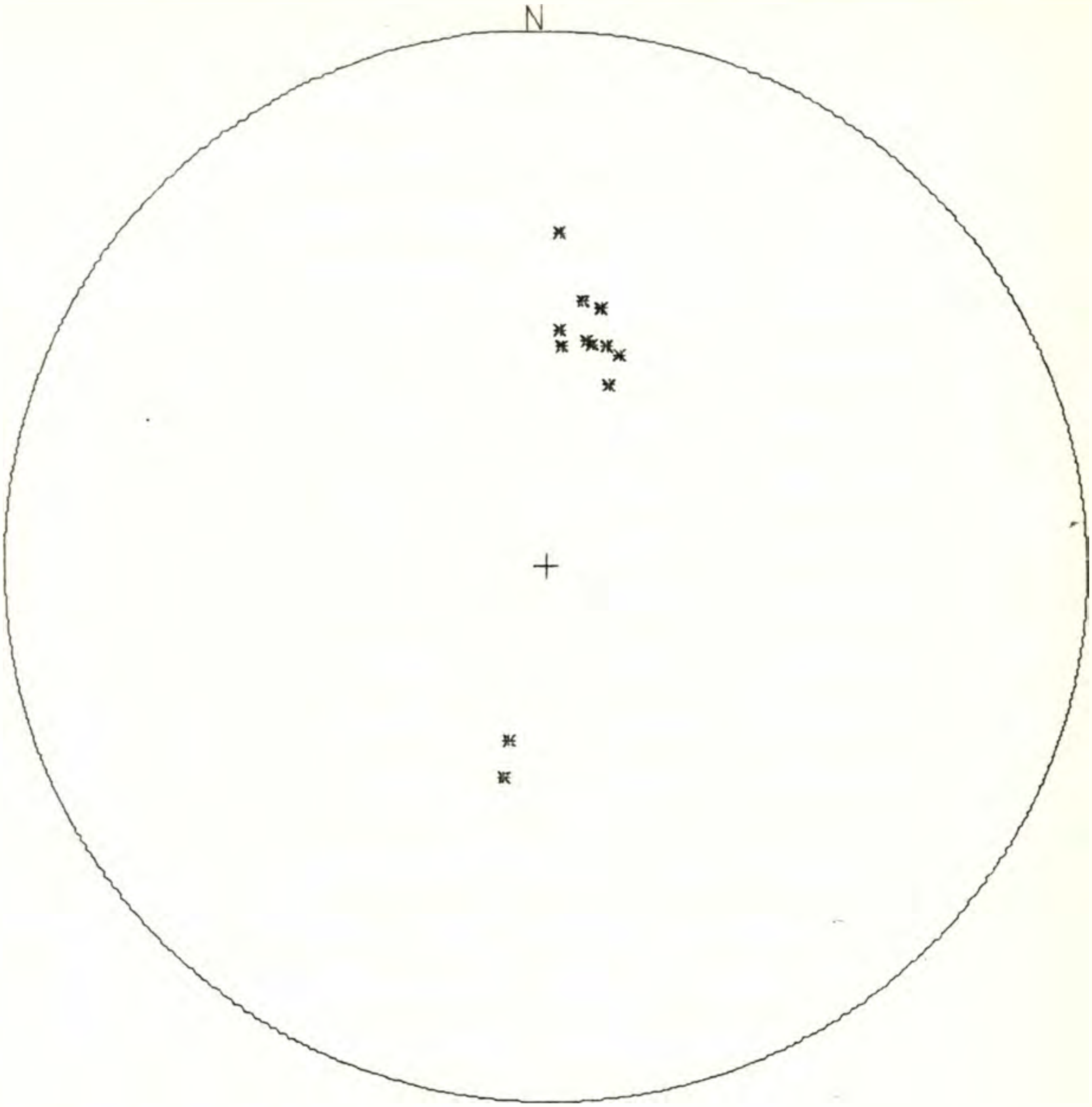
77-29B, NRM MERWIN LAKE 1

SAMPLE NUMBER	DECLINATION	INCLINATION
245	19.39	55.64
246	19.34	60.53
247	192.00	62.81
248	12.08	55.13
249	191.42	56.95
250	12.44	49.10
251	2.68	37.90
252	3.77	53.60
253	10.64	54.57
254	15.73	54.77
255	4.48	55.94
256	8.13	48.53

R= 10.85482 DECLINATION= 10.17 INCLINATION= 62.50

ALPHA= 14.77 DELTA= 25.23 KAPPA= 9.61

SITE LATITUDE= 45.98 SITE LONGITUDE=-122.45



77-29B, NRM MERWIN LAKE 1

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-29B, 200 OE

DIP AZIMUTH = 210.0   DIP ANGLE = 23.0

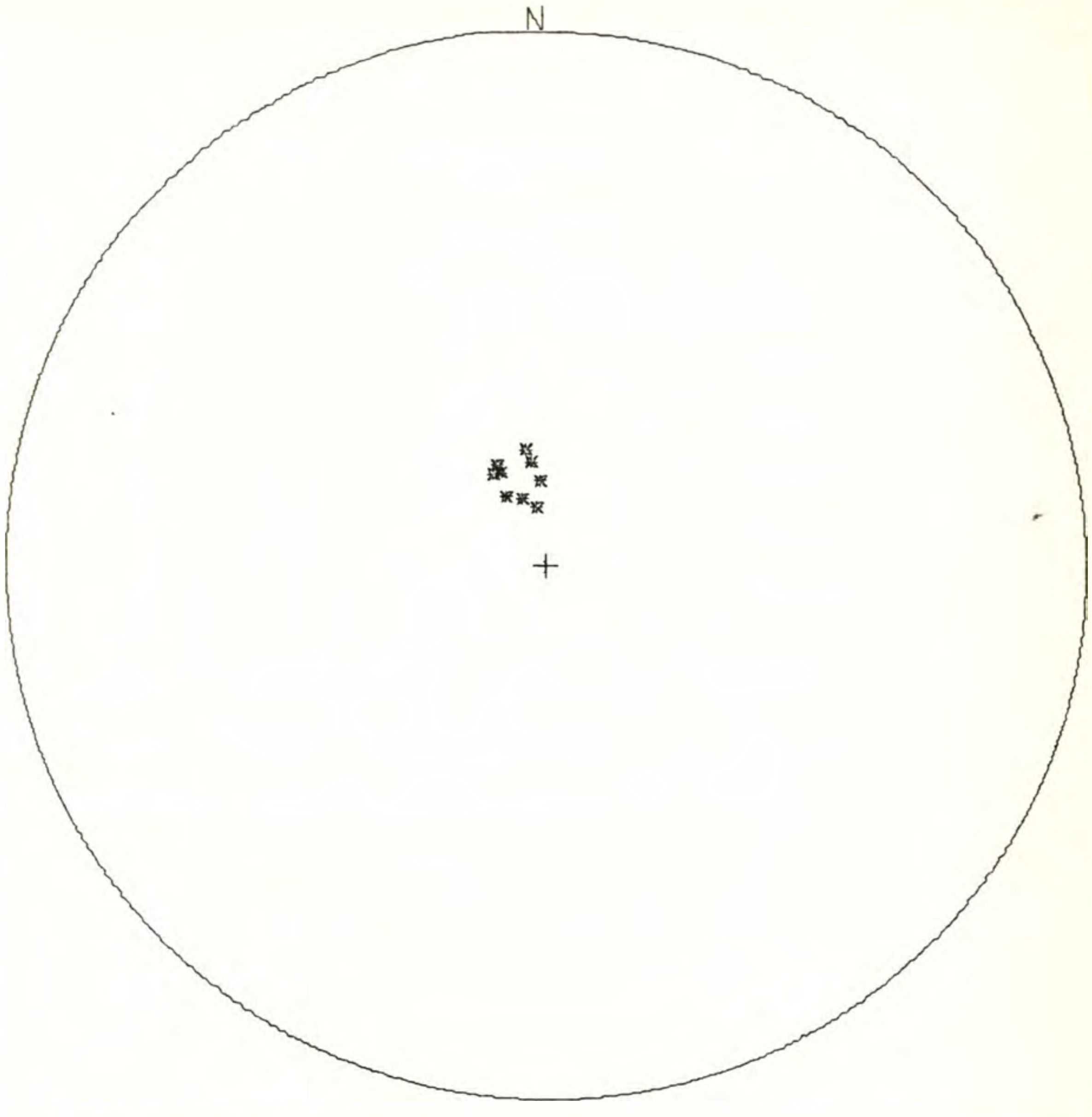
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
245	9.63	59.10	331.11	77.95
246	17.56	55.51	356.88	77.10
248	11.72	51.45	350.74	72.01
250	13.69	53.12	352.25	74.02
252	6.94	55.77	334.84	74.43
253	14.22	58.89	341.23	79.23
254	19.12	59.52	351.83	81.09
255	5.05	56.11	330.95	74.08
256	5.59	54.59	334.93	73.02

R =   8.98094   DECLINATION= 342.42   INCLINATION= 76.07

ALPHA= 2.52   DELTA= 3.73   KAPPA=   419.69

PLAT= 69.81   PLONG=-145.34   DELP = 4.29

DECLM= 4.64   STLAT= 45.98   STLONG=-122.45



77-29B, 200 ØE

FISHER ON SAMPLE DIRECTIONS

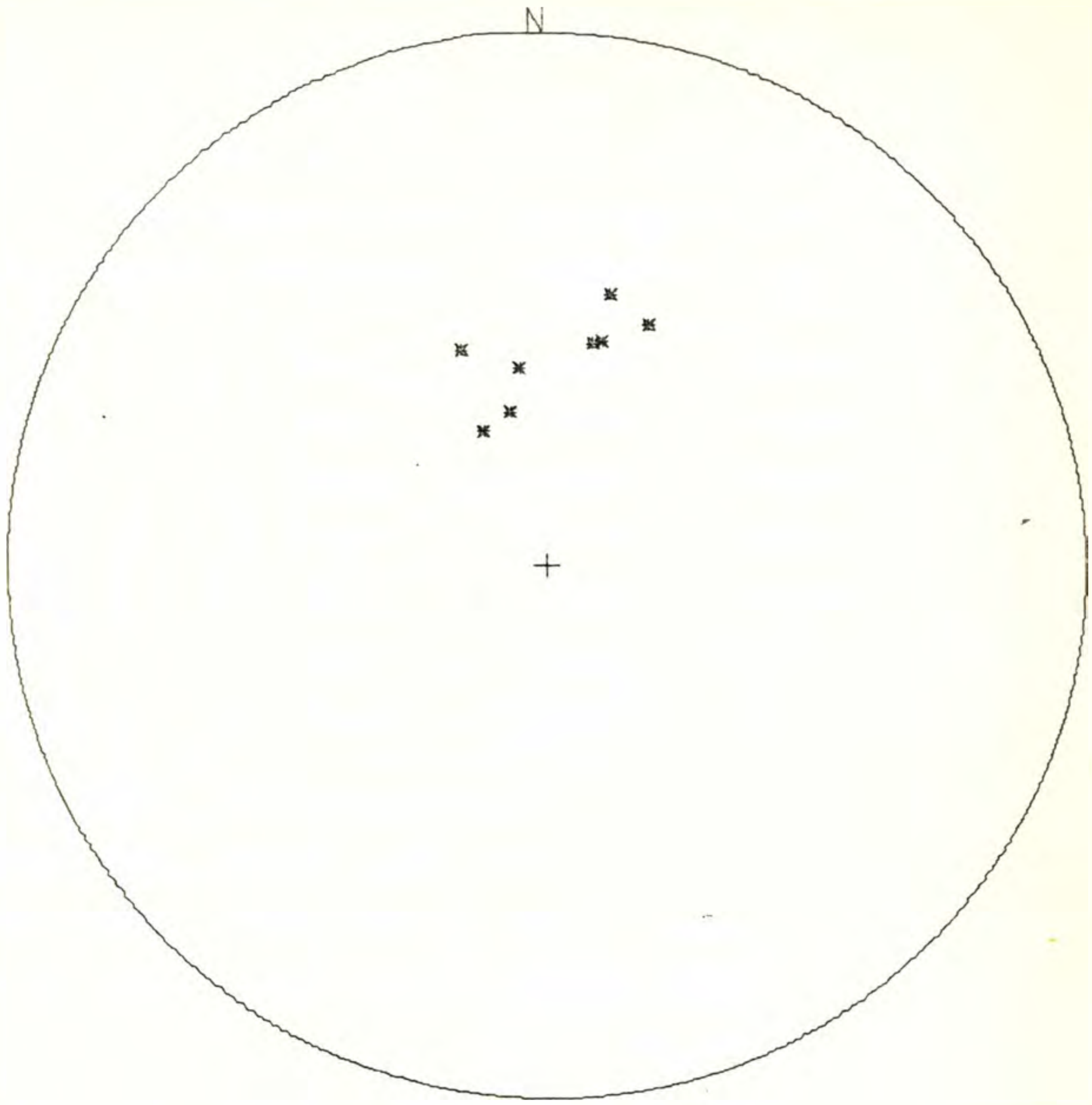
77-30B, NRM MERWIN LAKE 3

SAMPLE NUMBER	DECLINATION	INCLINATION
257	14.12	54.21
258	13.34	46.66
259	23.01	49.43
260	335.83	67.41
261	347.34	65.94
262	338.99	54.37
263	11.88	54.88
264	352.74	59.33

R= 7.84305 DECLINATION= 2.10 INCLINATION= 57.64

ALPHA= 8.38 DELTA= 11.37 KAPPA= 44.60

SITE LATITUDE= 45.98 SITE LONGITUDE=-122.45



77-30B. NRM MERWIN LAKE 3

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-30B, 200 OE

DIP AZIMUTH = 240.0 DIP ANGLE = 20.0

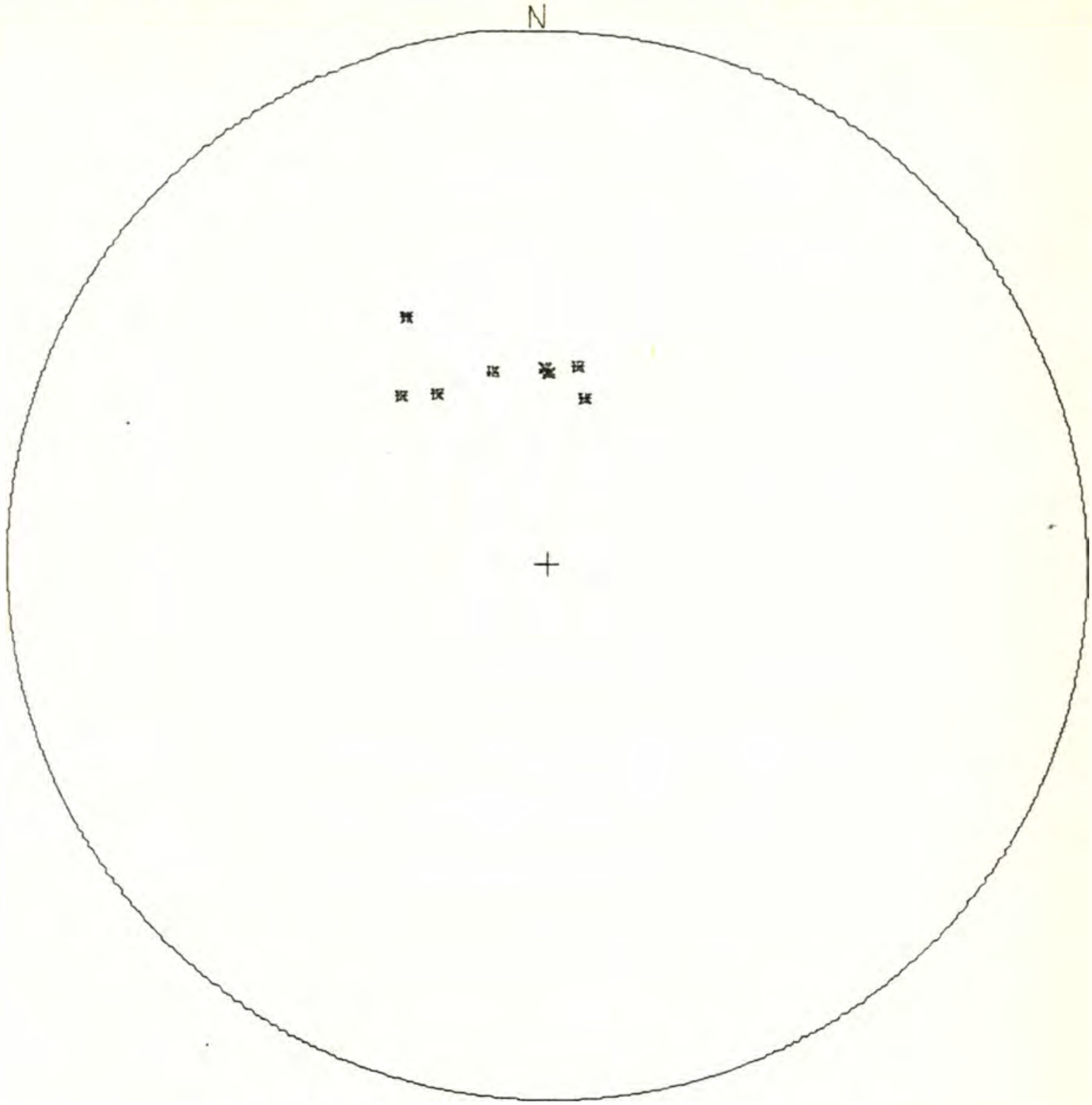
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
257	21.77	47.16	0.83	60.66
258	20.65	46.65	359.88	59.87
259	31.29	47.79	12.95	63.84
260	350.35	42.30	330.95	46.09
261	348.78	54.38	319.54	55.89
262	357.85	54.36	327.54	58.96
263	26.06	44.14	8.72	59.10
264	10.14	49.83	344.70	59.35

R= 7.85201 DECLINATION= 346.56 INCLINATION= 59.39

ALPHA= 8.14 DELTA= 11.04 KAPPA= 47.30

PLAT= 78.63 PLONG= 121.78 DELP = 9.15

DECLM= 12.20 STLAT= 45.98 STLONG=-122.45



77-30B, 200 OE

FISHER ON SAMPLE DIRECTIONS

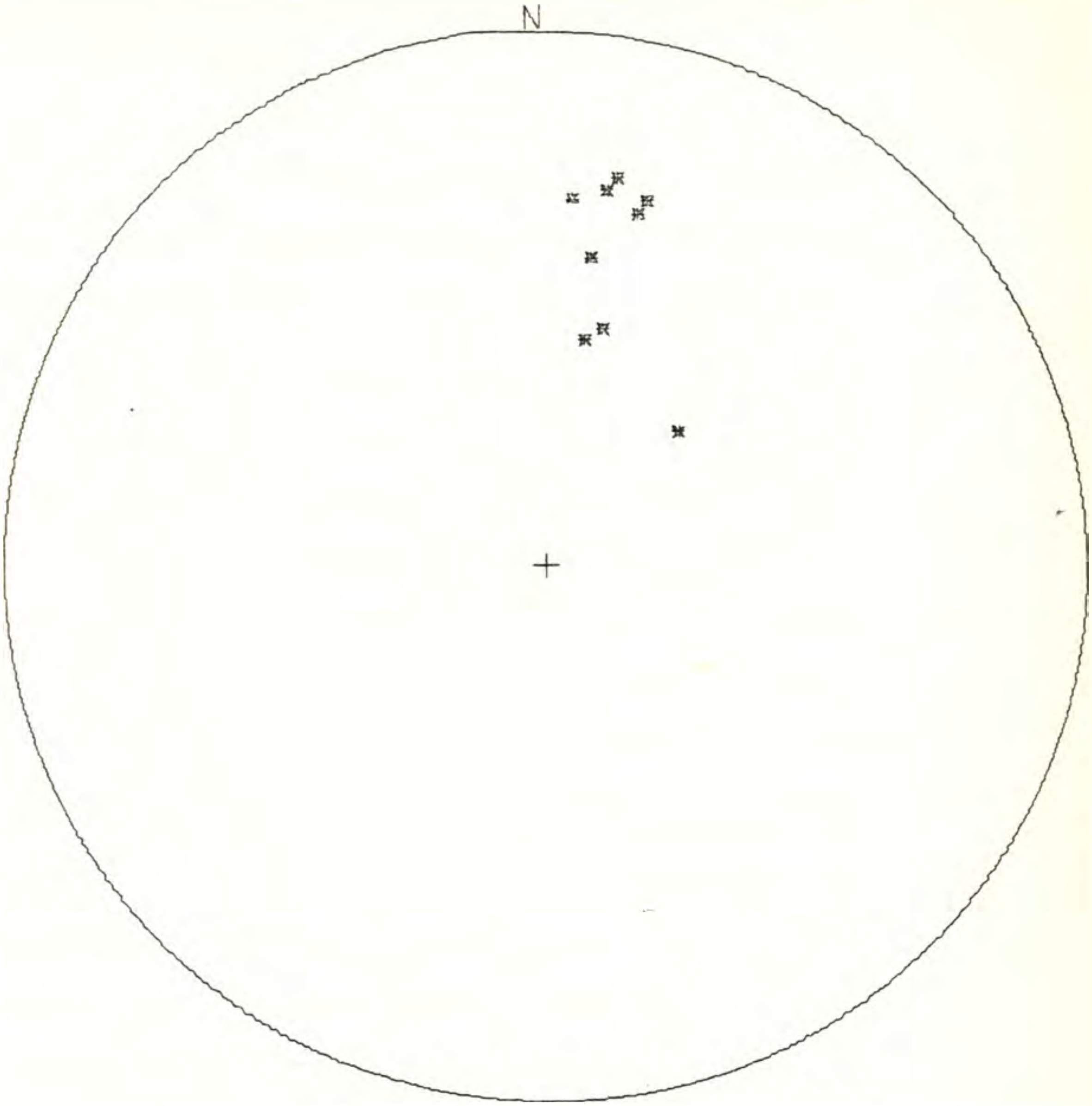
77-31B, NRM MERWIN LAKE 2

SAMPLE NUMBER	DECLINATION	INCLINATION
265	10.05	54.71
266	14.85	32.79
267	44.54	61.34
268	13.61	52.37
269	9.63	29.81
270	8.60	41.55
271	15.73	30.15
272	10.77	27.32
273	4.60	31.98

R= 8.73662 DECLINATION= 13.25 INCLINATION= 40.54

ALPHA= 9.49 DELTA= 13.90 KAPPA= 30.37

SITE LATITUDE= 45.98 SITE LONGITUDE=-122.45



77-31B. NRM MERWIN LAKE 2

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-31B, 100 OE

DIP AZIMUTH = 180.0 DIP ANGLE = 23.0

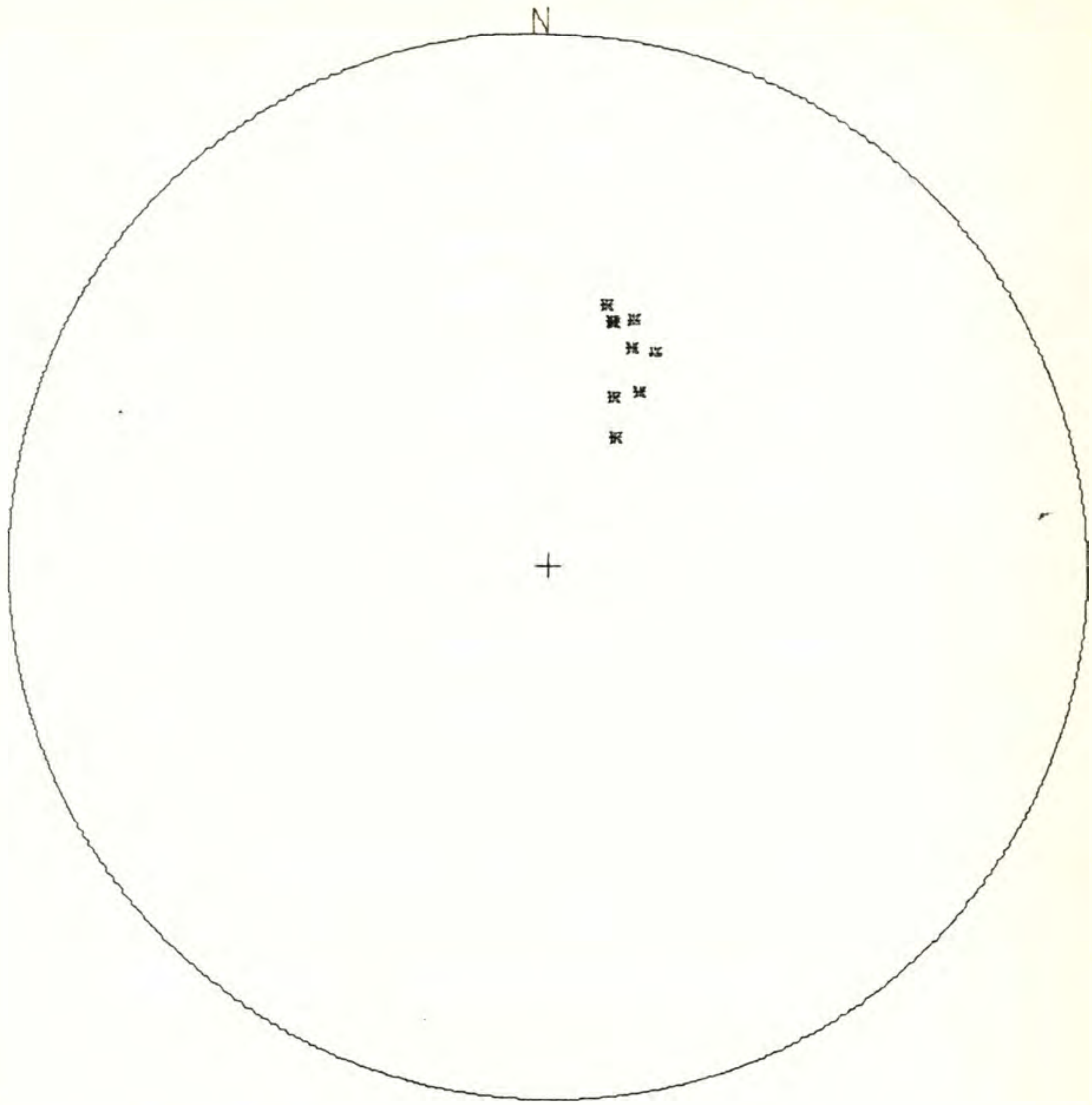
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
265	14.41	46.05	27.10	67.72
266	14.19	31.62	20.61	53.63
267	17.15	38.20	27.27	59.62
268	12.52	39.96	20.78	62.08
269	10.63	28.32	14.88	50.78
270	18.01	31.47	25.92	52.89
271	13.65	27.30	18.81	49.43
272	10.18	28.08	14.22	50.59
273	9.10	25.63	12.36	48.25

R= 8.93372 DECLINATION= 19.59 INCLINATION= 55.10

ALPHA= 4.70 DELTA= 6.96 KAPPA= 120.71

PLAT= 72.00 PLONG= -4.30 DELP = 4.75

DECLM= 6.68 STLAT= 45.98 STLONG=-122.45



77-31B, 100 OE

FISHER ON SAMPLE DIRECTIONS

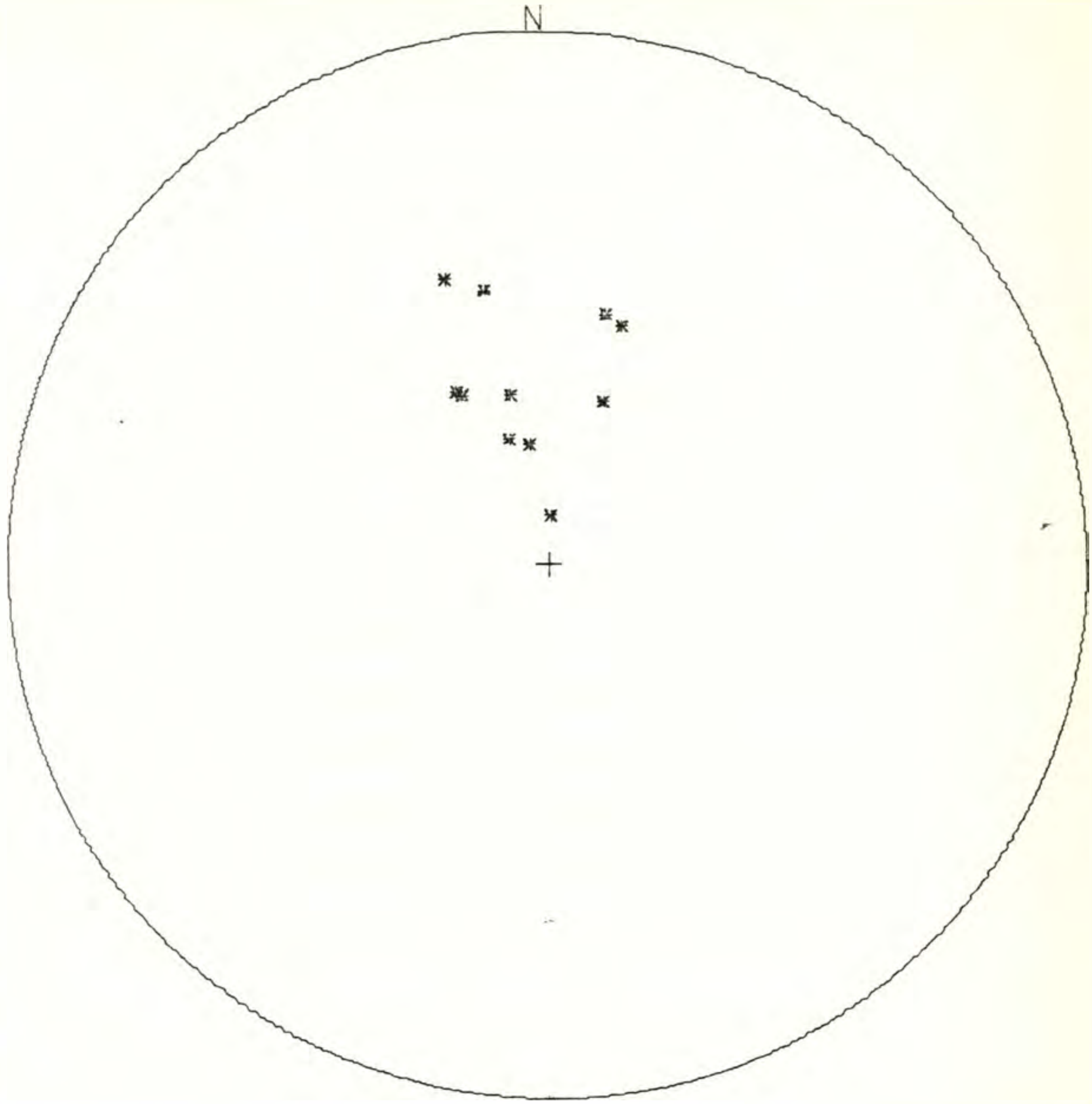
77-32B, NRM MERWIN LAKE 4

SAMPLE NUMBER	DECLINATION	INCLINATION
274	17.57	51.36
275	333.80	61.06
276	347.86	46.33
277	3.34	82.50
278	343.88	70.07
279	333.03	60.01
280	13.29	50.29
281	19.17	63.50
282	341.01	42.70
283	352.37	71.42
284	348.33	63.33

R= 10.67569 DECLINATION= 353.70 INCLINATION= 61.27

ALPHA= 8.35 DELTA= 13.95 KAPPA= 30.83

SITE LATITUDE= 45.98 SITE LONGITUDE=-122.55



77-32B, NRM MERWIN LAKE 4

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-32B, 150 OE

DIP AZIMUTH = 225.0   DIP ANGLE = 17.0

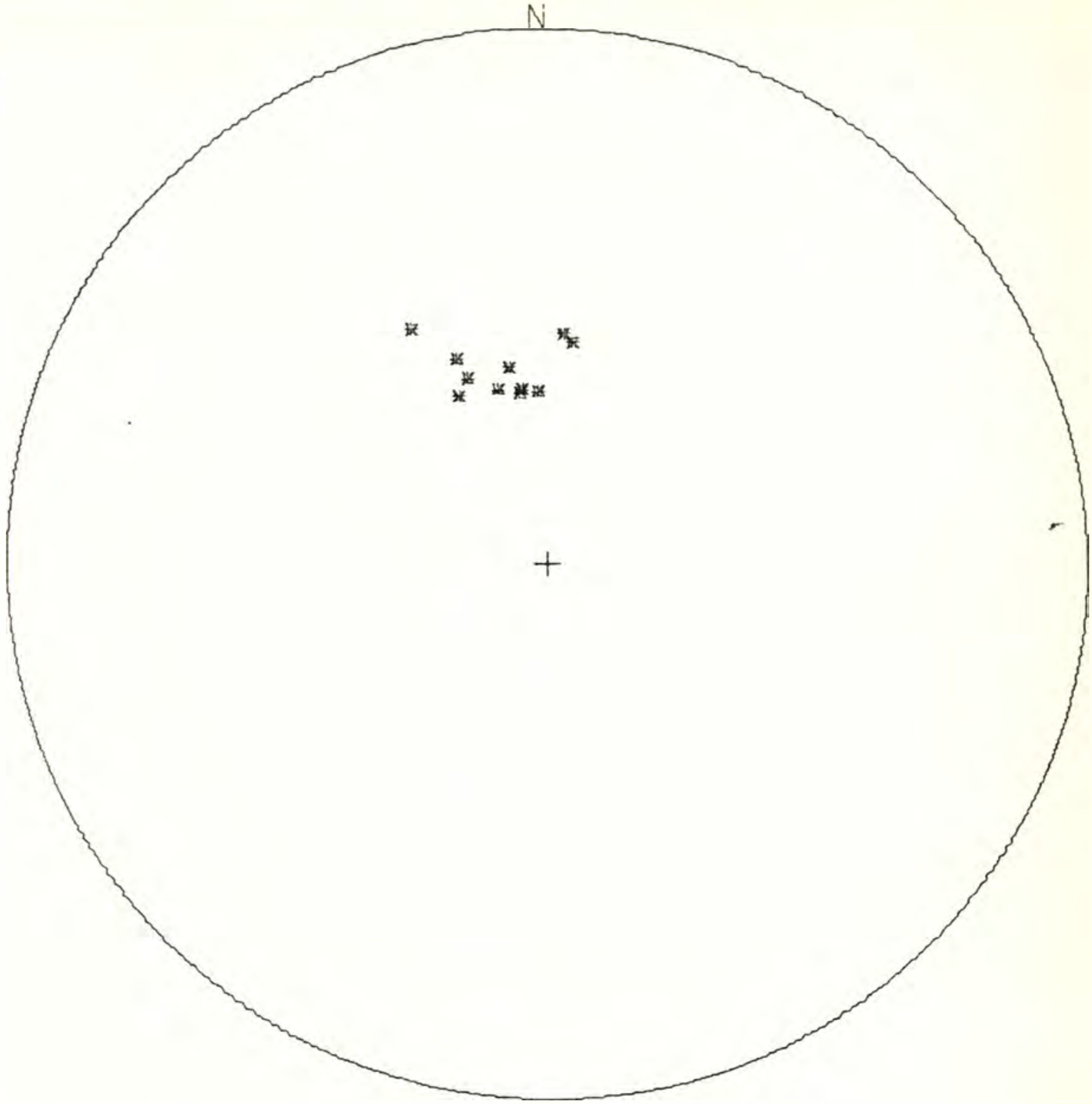
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
274	17.14	41.29	6.56	55.61
275	6.42	47.42	349.55	59.18
276	10.43	50.49	352.34	63.00
277	13.80	50.11	357.11	63.40
278	357.56	49.72	337.28	59.03
279	346.10	41.40	330.42	48.22
280	14.99	40.26	4.25	54.22
281	10.02	51.03	351.36	63.40
282	354.90	46.77	336.51	55.61
283	4.94	51.12	344.85	62.24
284	355.89	52.35	333.10	60.93

R= 10.89869   DECLINATION= 347.27   INCLINATION= 59.20

ALPHA= 4.62   DELTA= 7.78   KAPPA= 98.71

PLAT= 78.95   PLONG= 119.19   DELP = 5.17

DECLM= 6.91   STLAT= 45.98   STLONG=-122.55



77-32B, 150 OE

FISHER ON SAMPLE DIRECTIONS

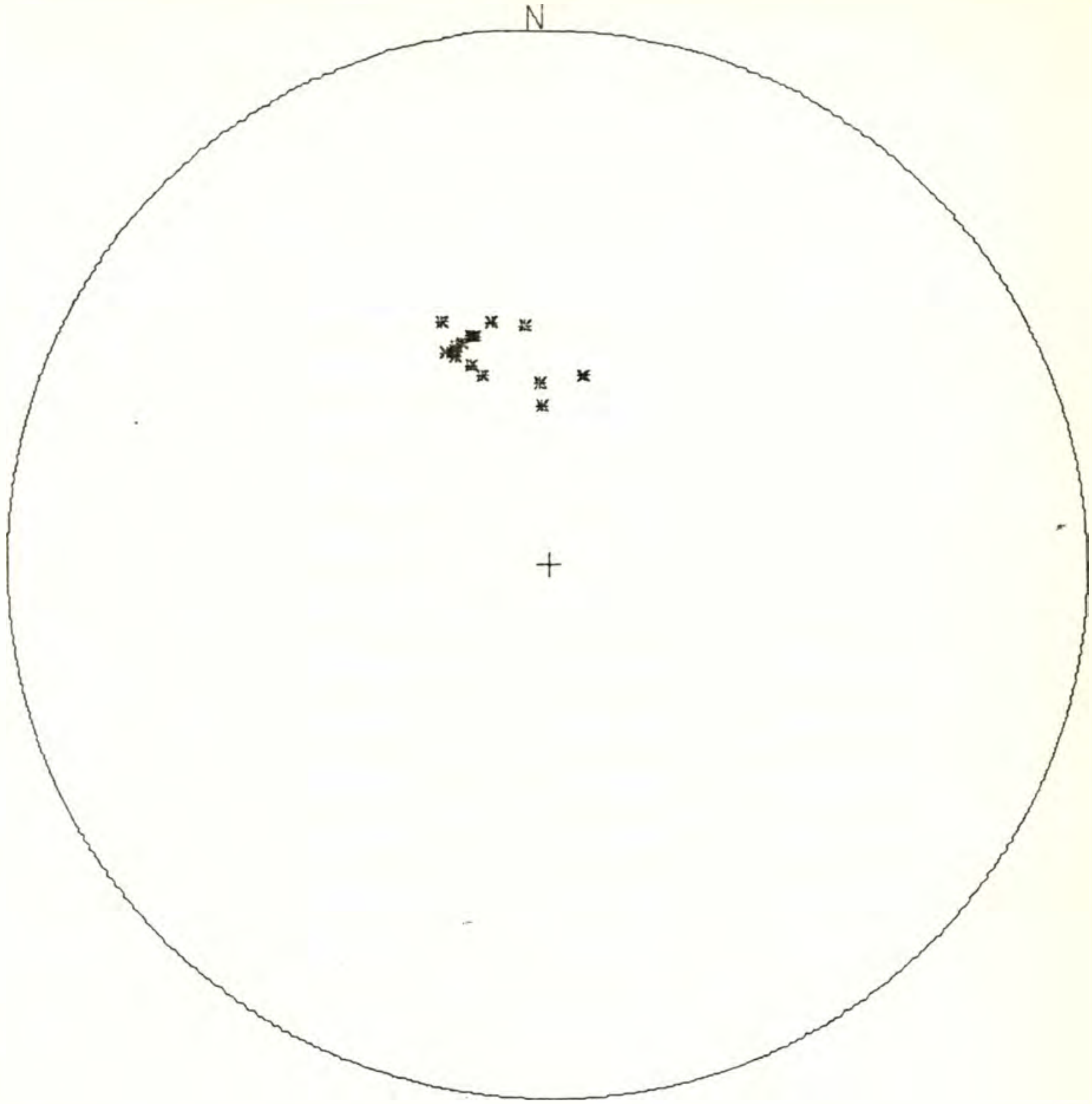
77-33B, NRM YALE LAKE 1

SAMPLE NUMBER	DECLINATION	INCLINATION
285	358.24	65.65
286	347.51	51.64
287	341.41	59.26
288	337.23	54.16
289	336.80	54.84
290	342.16	52.88
291	335.03	53.90
292	337.10	49.10
293	339.65	57.28
294	342.71	52.97
295	339.41	53.43
296	354.93	52.96
297	342.76	53.02
298	337.96	53.62
299	10.91	60.30
300	357.80	62.06

R= 15.88943 DECLINATION= 344.37 INCLINATION= 55.80

ALPHA= 3.18 DELTA= 6.74 KAPPA= 135.66

SITE LATITUDE= 46.03 SITE LONGITUDE=-122.33



77-33B, NRM YALE LAKE 1

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-33B, 150 OE

DIP AZIMUTH = 112.0 DIP ANGLE = 25.0

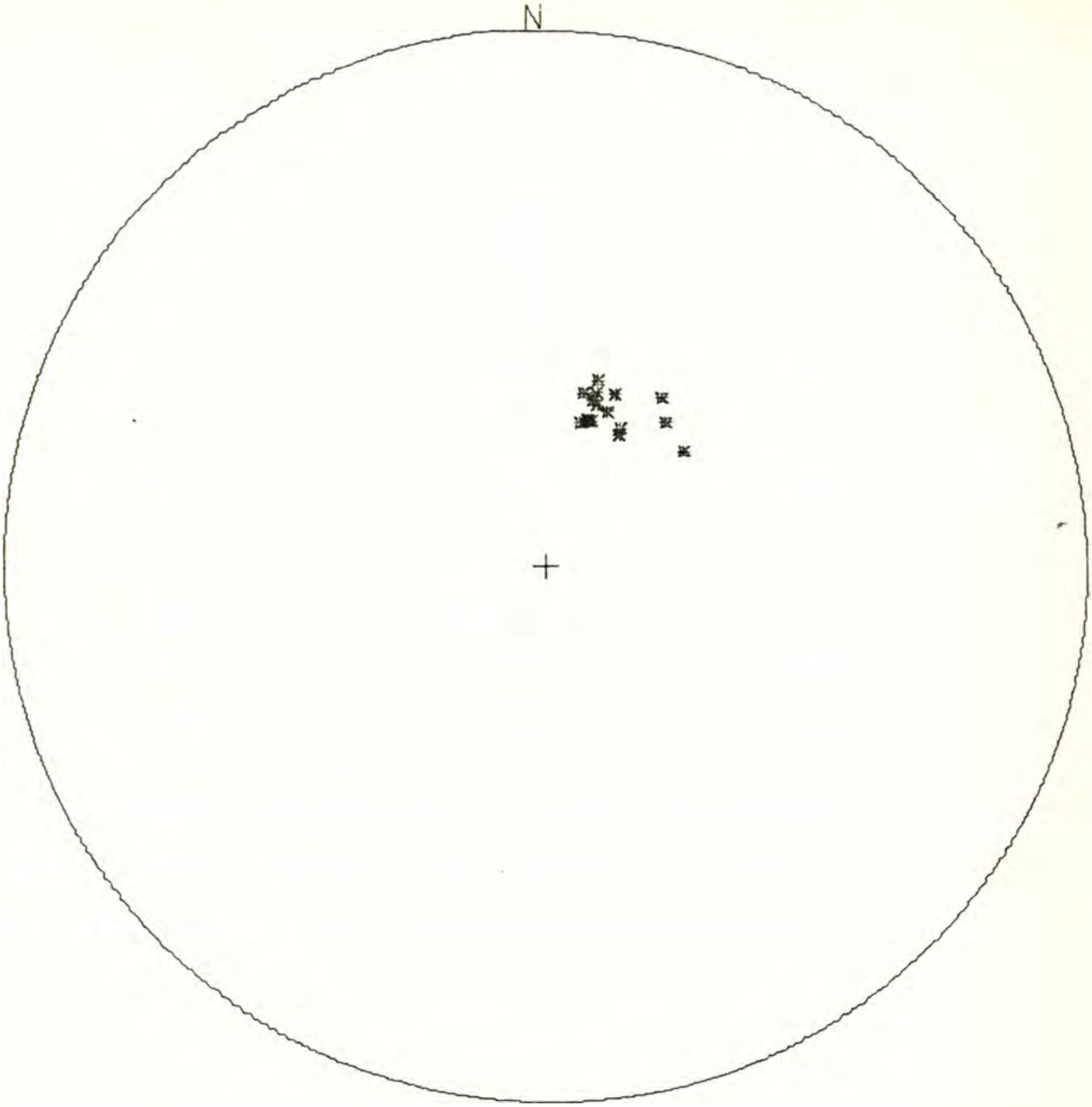
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
285	357.64	63.66	49.77	62.82
286	343.90	52.81	21.84	61.60
287	340.04	58.66	28.75	67.08
288	334.70	54.50	15.81	66.66
289	335.11	55.03	17.20	66.85
290	334.47	54.83	16.19	66.99
291	332.68	54.37	13.48	67.42
292	338.27	52.31	15.72	63.61
293	340.09	54.79	21.50	64.59
294	340.13	51.48	16.33	62.22
295	337.22	50.78	12.36	62.92
296	354.80	55.11	34.17	58.64
297	338.79	53.17	17.59	64.01
298	341.69	49.89	15.67	60.38
299	353.95	58.96	39.37	61.52
300	341.00	57.94	28.06	66.24

R= 15.93277 DECLINATION= 22.97 INCLINATION= 64.35

ALPHA= 2.47 DELTA= 5.25 KAPPA= 223.12

PLAT= 74.12 PLONG= -41.09 DELP = 3.17

DECLM= 3.96 STLAT= 46.03 STLONG=-122.33



77-33B, 150 OE

FISHER ON SAMPLE DIRECTIONS

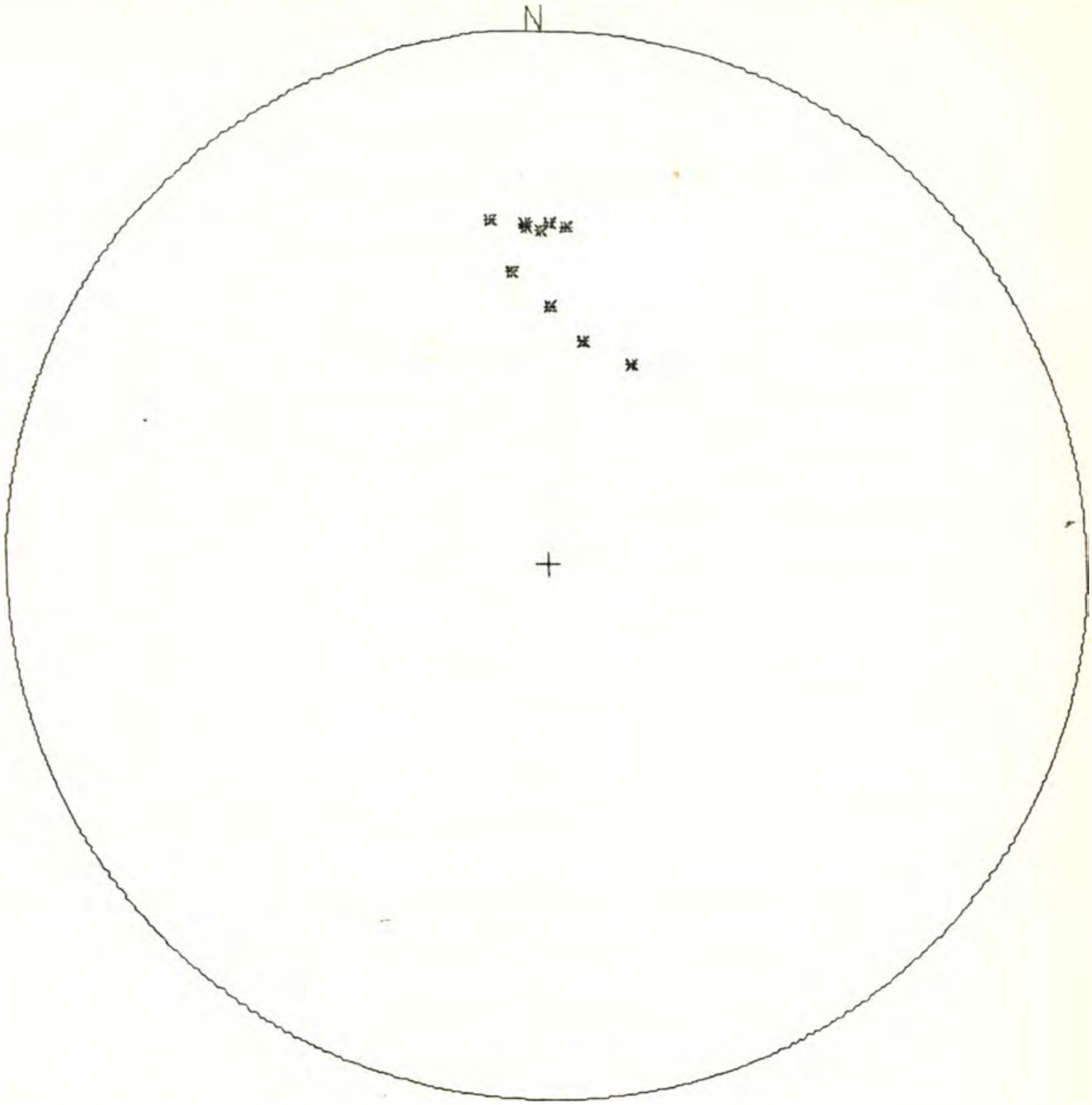
77-34B, NRM YALE LAKE 2

SAMPLE NUMBER	DECLINATION	INCLINATION
301	3.64	36.88
302	23.36	56.32
303	357.06	36.85
304	359.43	37.52
305	1.23	50.00
306	9.91	55.02
307	353.83	43.98
308	356.99	36.31
309	351.32	35.01
310	1.08	36.24

R= 9.85240 DECLINATION= 0.84 INCLINATION= 42.67

ALPHA= 6.24 DELTA= 9.86 KAPPA= 60.97

SITE LATITUDE= 46.05 SITE LONGITUDE=-122.33



77-34B, NRM YALE LAKE 2

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-34B, 100 OE

DIP AZIMUTH = 105.0   DIP ANGLE = 20.0

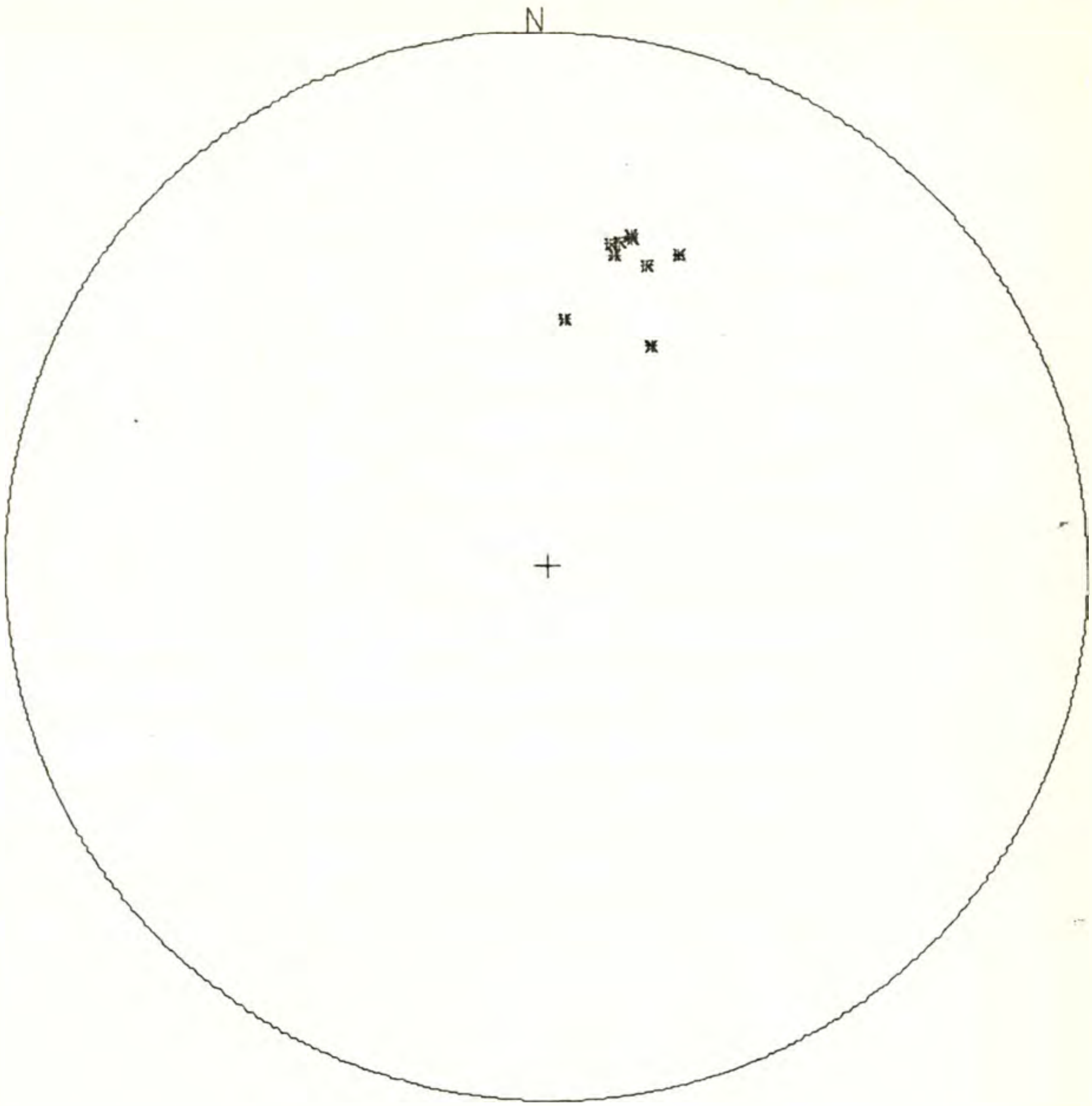
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
301	7.79	37.13	23.09	36.97
302	359.55	51.44	25.50	52.33
303	358.23	34.47	12.83	37.82
304	0.36	34.18	14.69	36.83
305	343.37	44.24	4.37	51.64
307	356.65	34.60	11.39	38.48
308	356.76	36.52	12.54	40.18
309	0.36	33.74	14.46	36.43
310	1.78	38.68	18.46	40.42

R= 8.92761   DECLINATION= 15.27   INCLINATION= 41.36

ALPHA= 4.92   DELTA= 7.27   KAPPA= 110.51

PLAT= 64.54   PLONG= 23.57   DELP = 3.66

DECLM= 6.00   STLAT= 46.05   STLONG=-122.33



77-34B, 100 OE

FISHER ON SAMPLE DIRECTIONS

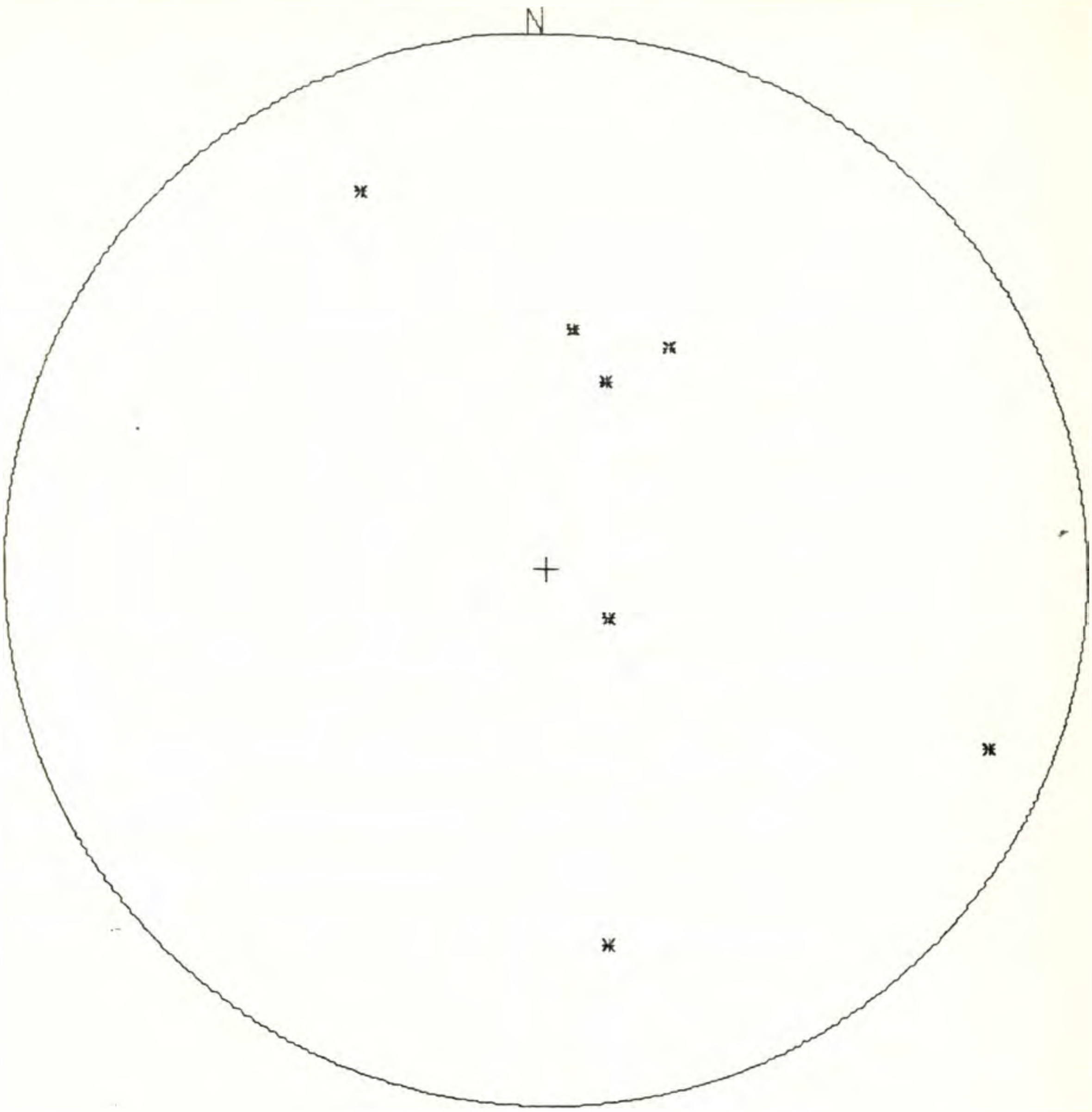
77-35B, NRM E. FORK LEWIS RV 1

SAMPLE NUMBER	DECLINATION	INCLINATION
311	170.94	-29.63
312	17.89	59.83
313	128.32	78.00
314	6.62	52.63
315	28.91	50.91
316	112.16	-12.54
317	334.42	22.87

R= 3.54471 DECLINATION= 50.30 INCLINATION= 60.68

ALPHA= 68.36 DELTA= 59.58 KAPPA= 1.74

SITE LATITUDE= 45.85 SITE LONGITUDE=-122.27



77-35B, NRM E. FØRK LEWIS RV 1

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-35B, 150 OE

DIP AZIMUTH = 230.0   DIP ANGLE = 10.0

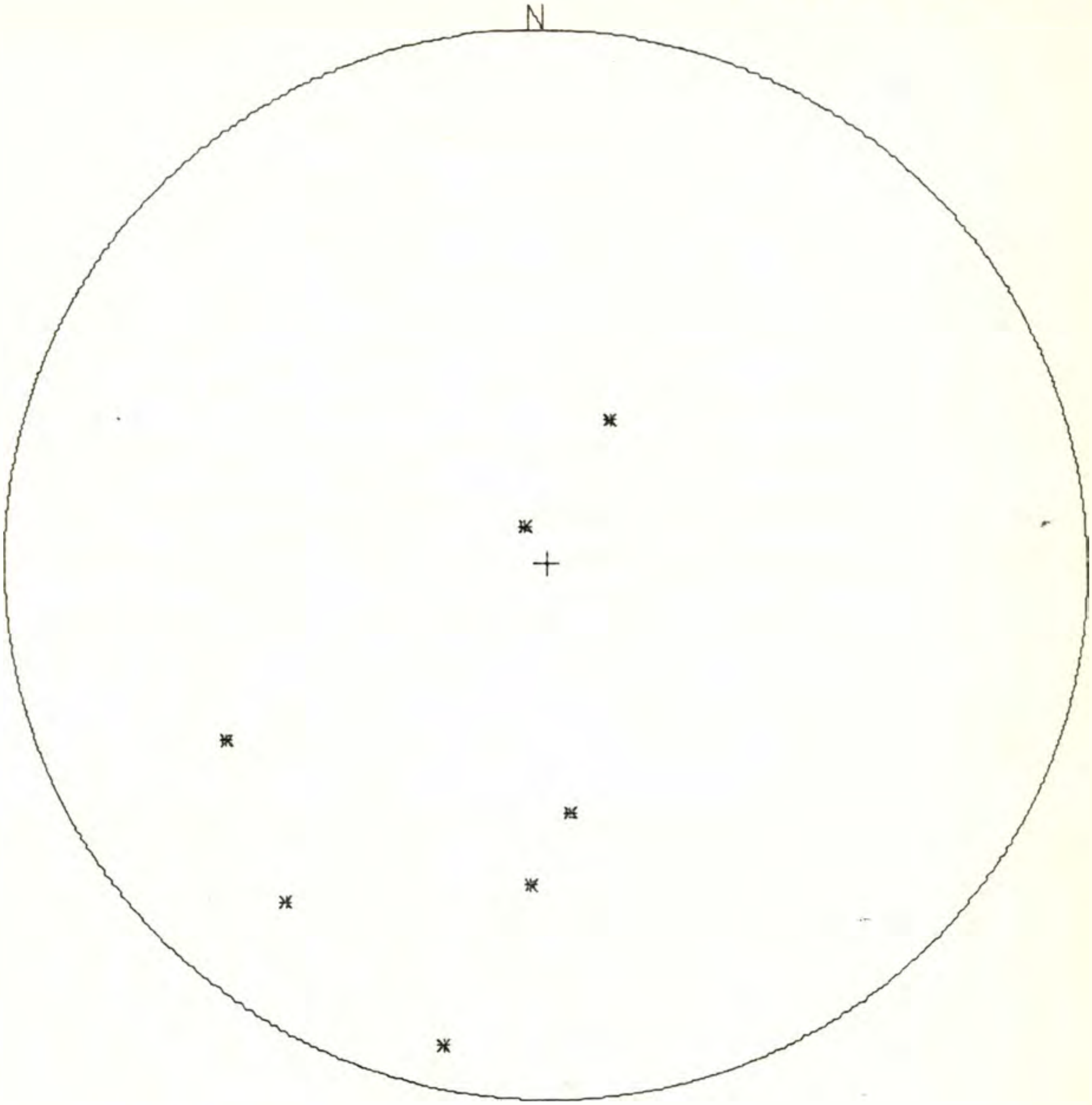
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
311	242.69	42.54	241.10	32.75
312	20.12	77.04	331.28	83.46
313	190.80	16.80	192.23	8.96
314	218.12	-11.67	217.49	-21.45
315	30.62	56.51	23.53	65.74
316	183.64	-45.07	174.94	-51.43
317	188.26	-32.49	183.16	-39.66

R= 3.42635   DECLINATION= 204.69   INCLINATION= 13.78

ALPHA= 71.06   DELTA= 60.69   KAPPA= 1.68

PLAT= -32.74   PLONG=-151.80   DELP = 37.11

DECLM= 72.62   STLAT= 45.85   STLONG=-122.27



77-35B, 150 OE

FISHER ON SAMPLE DIRECTIONS

77-36B, NRM E. FORK LEWIS RV 2

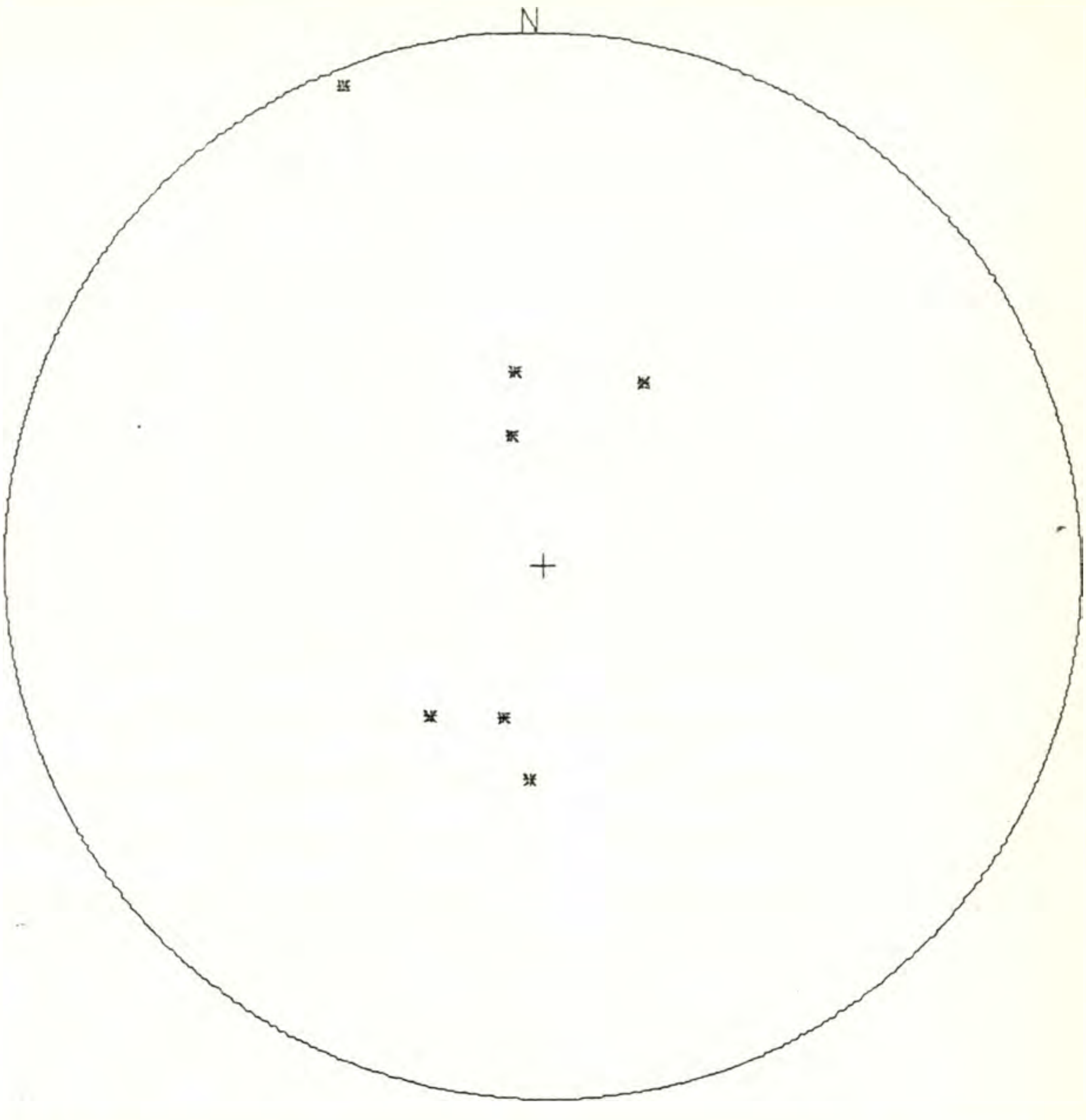
SAMPLE NUMBER	DECLINATION	INCLINATION
318	194.87	-66.00
319	347.17	69.43
320	338.09	3.24
321	352.48	59.70
322	217.05	-61.23
323	184.01	-56.99
324	28.61	57.87

INVALID COSINE VALUE 0.648 5.080 -2.290 -2.290

R= 1.15127 DECLINATION= 322.81 INCLINATION= 3.70

ALPHA=180.00 DELTA= 80.53 KAPPA= 1.03

SITE LATITUDE= 45.85 SITE LONGITUDE=-122.33



77-36B, NRM E. FØRK LEWIS RV 2

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-36B, 150 OE

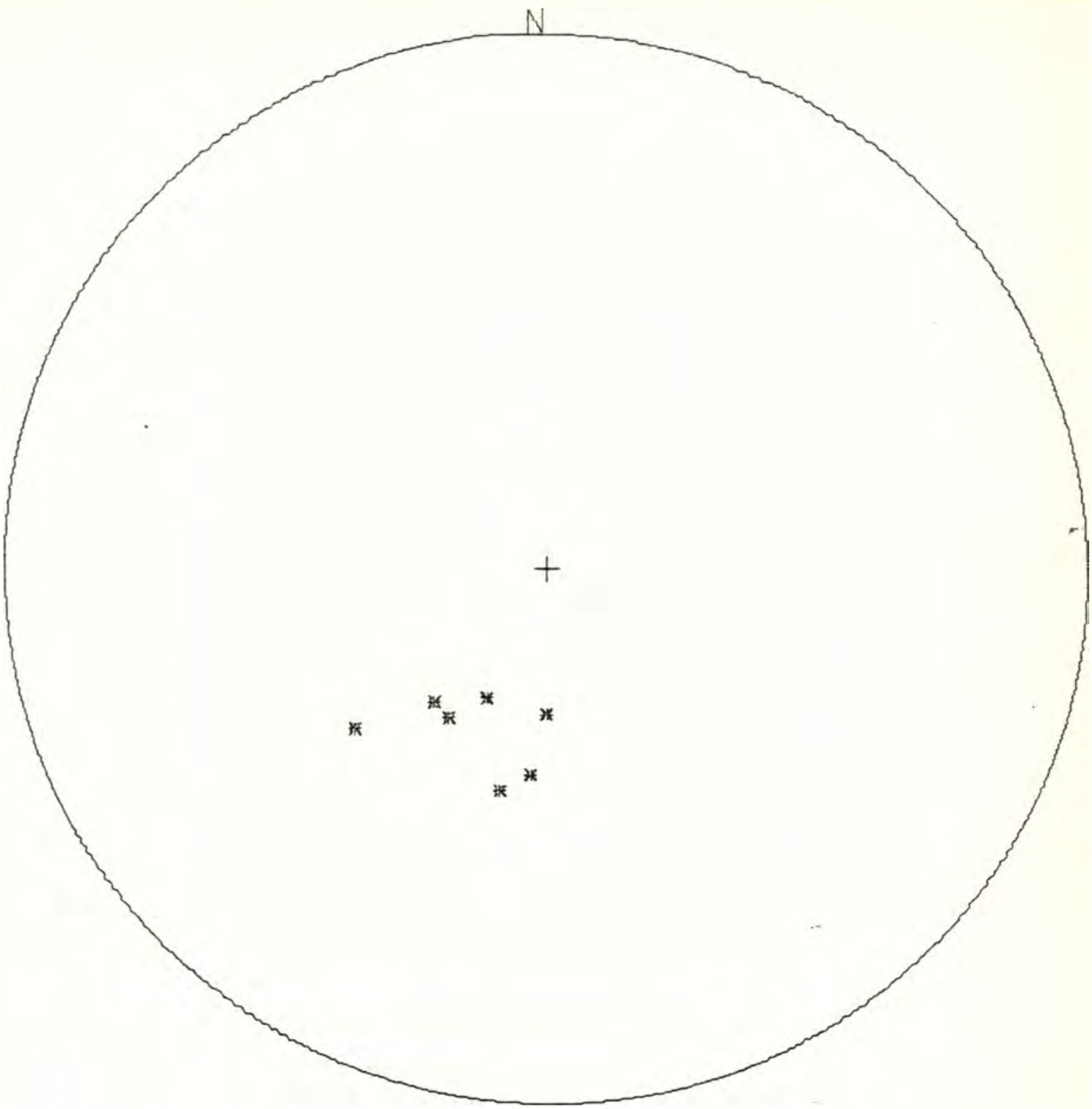
SAMPLE NUMBER	DECLINATION	INCLINATION
318	204.87	-68.41
319	230.01	-51.67
320	219.99	-63.43
321	213.22	-62.82
322	192.08	-55.08
323	180.30	-67.72
324	184.55	-58.21

R= 6.88746 DECLINATION= 204.50 INCLINATION= -62.22

ALPHA= 8.34 DELTA= 10.29 KAPPA= 53.31

PLAT= 72.49 PLONG= -33.45 DELP = 10.10

DECLM=-12.98 STLAT= 45.85 STLONG=-122.33



77-36B, 150 OE

FISHER ON SAMPLE DIRECTIONS

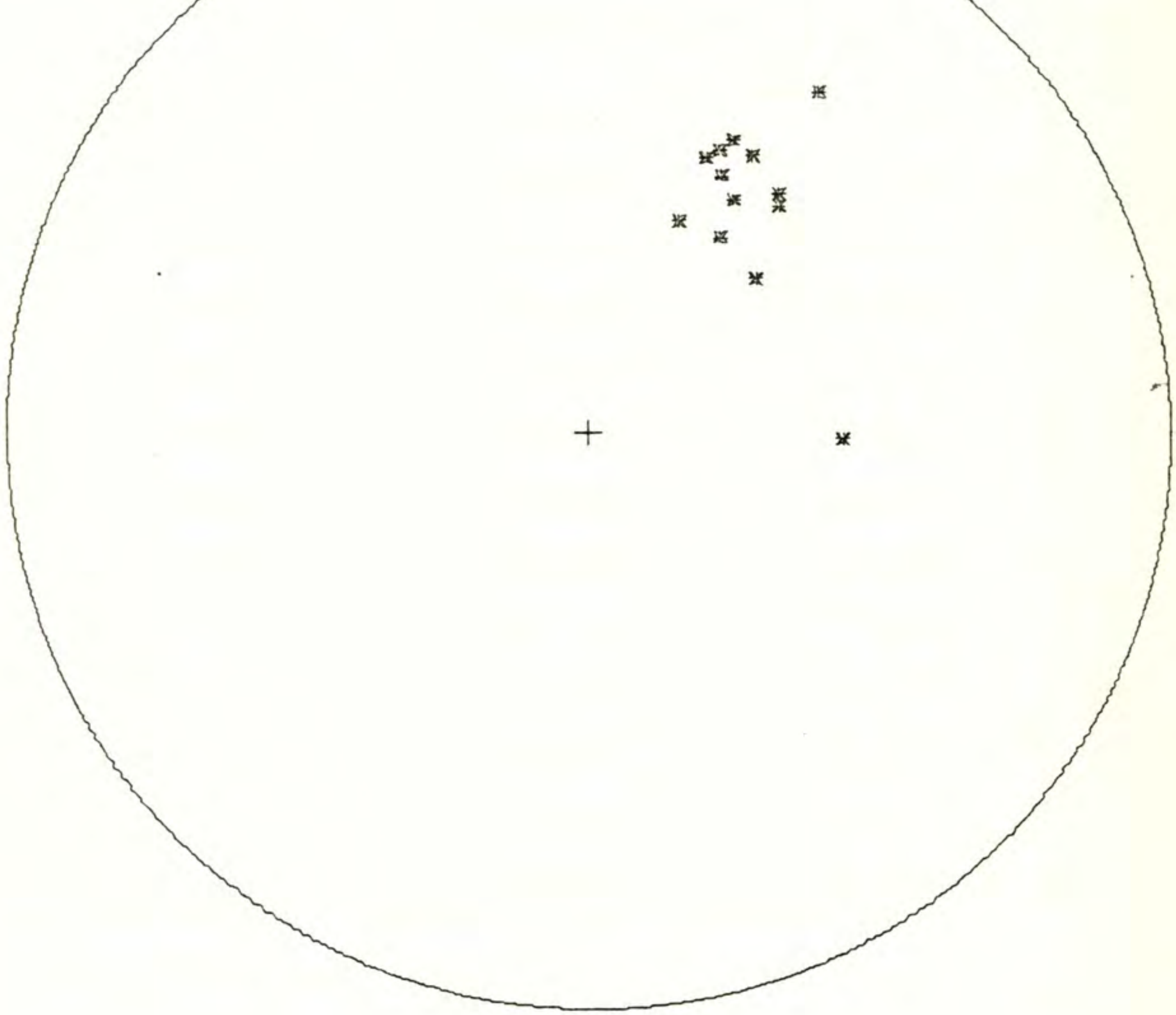
77-37B, NRM COWEMAN RIVER 5

SAMPLE NUMBER	DECLINATION	INCLINATION
335	26.35	42.61
336	30.47	43.39
337	24.70	44.88
338	23.25	46.77
339	23.10	57.02
340	27.20	48.24
341	31.68	50.52
342	47.00	57.62
343	33.97	29.51
344	38.17	46.07
345	33.79	56.25
346	39.87	47.38
347	91.34	54.04

R= 12.67514 DECLINATION= 34.96 INCLINATION= 49.16

ALPHA= 6.91 DELTA= 12.84 KAPPA= 36.94

SITE LATITUDE= 46.17 SITE LONGITUDE=-122.75



77-37B. NRM COWEMAN RIVER 5

FISHER ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-37B, 150 OE

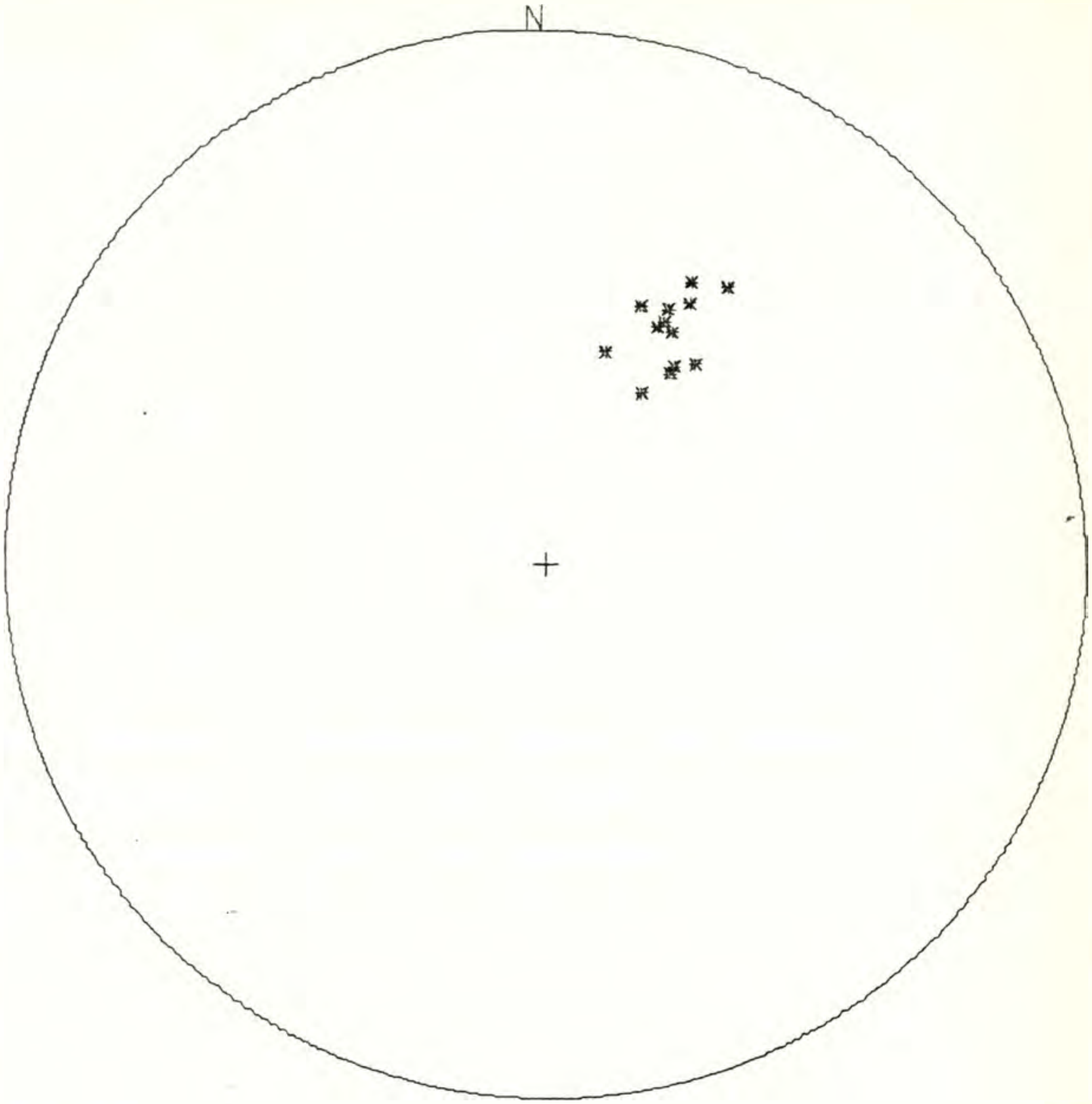
SAMPLE NUMBER	DECLINATION	INCLINATION
335	27.30	40.43
336	28.78	43.49
337	25.67	45.99
338	25.06	49.25
339	20.13	47.24
340	25.90	48.18
341	32.87	53.64
342	28.80	59.79
343	33.17	37.90
344	28.45	48.92
345	15.68	55.86
346	32.90	54.94
347	36.46	51.39

R= 12.90586 DECLINATION= 27.84 INCLINATION= 49.12

ALPHA= 3.69 DELTA= 6.90 KAPPA= 127.47

PLAT= 63.01 PLONG= -5.76 DELP = 3.23

DECLM= 4.88 STLAT= 46.17 STLONG=-122.75



77-37B, 150 0E

FISHER ON SAMPLE DIRECTIONS

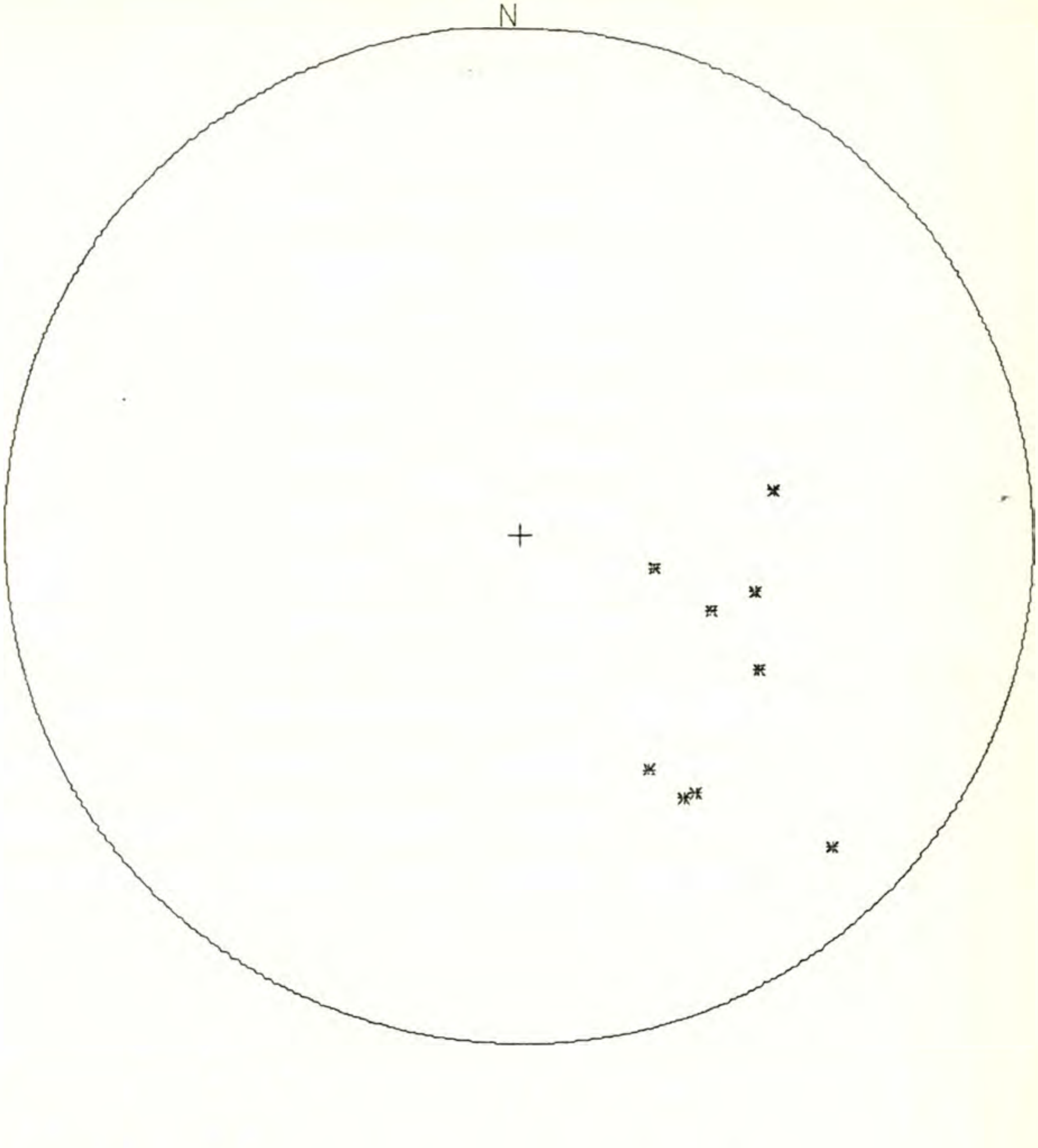
77-38B, NRM E. FORK LEWIS RV 3

SAMPLE NUMBER	DECLINATION	INCLINATION
348	79.73	48.31
349	148.57	-39.28
350	119.56	-45.60
351	135.41	14.80
352	111.59	57.17
353	146.17	-38.89
354	103.57	50.95
355	104.00	68.11
356	151.93	46.45

R= 6.07768 DECLINATION= 125.50 INCLINATION= 22.20

ALPHA= 38.59 DELTA= 47.52 KAPPA= 2.74

SITE LATITUDE= 45.85 SITE LONGITUDE=-122.40



77-38B. NRM E. FØRK LEWIS RV 3

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-38B, 150 OE

DIP AZIMUTH = 170.0   DIP ANGLE = 10.0

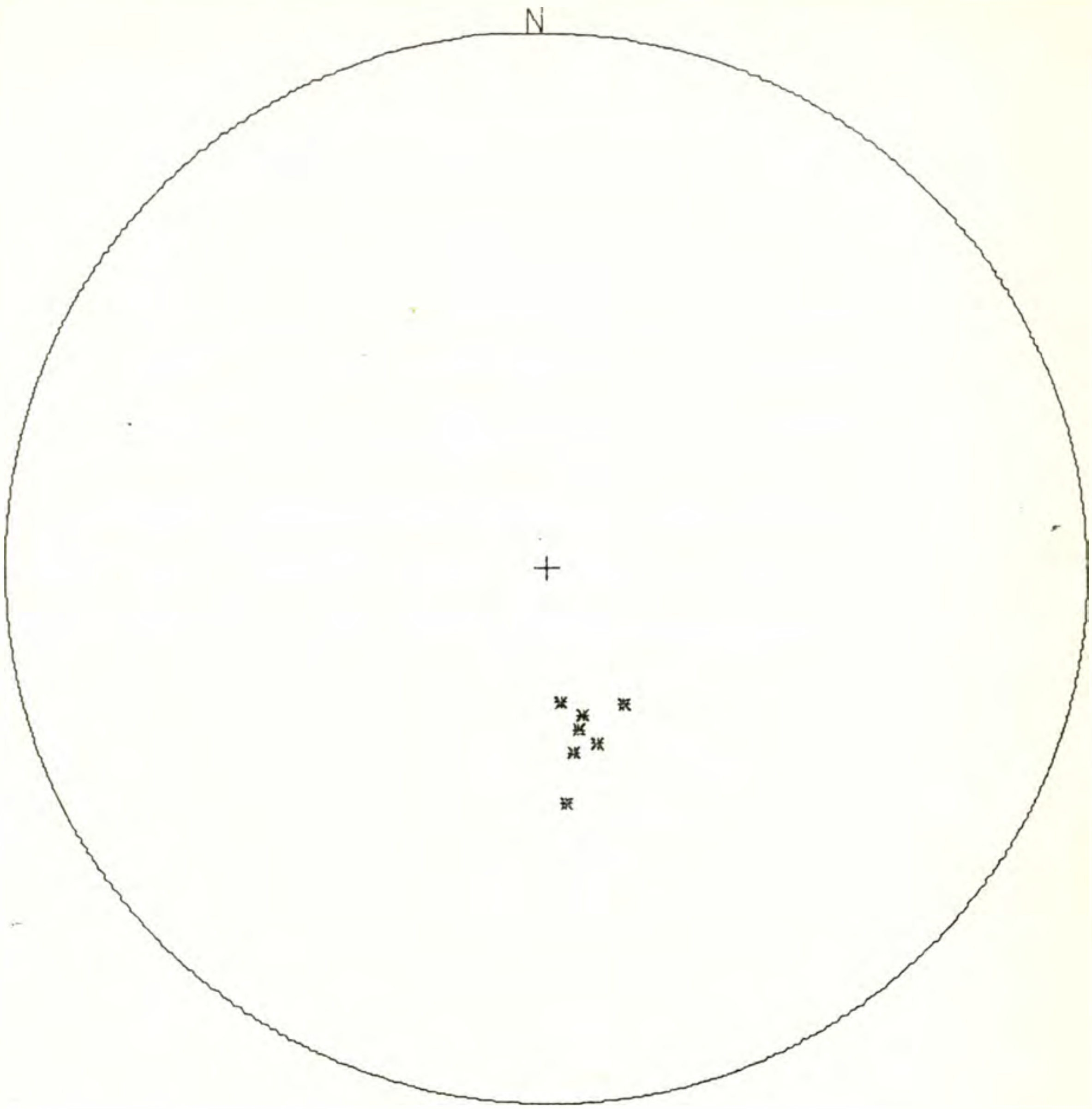
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
349	167.42	-56.92	166.41	-66.91
350	172.86	-59.50	174.14	-69.48
351	165.52	-52.20	164.12	-62.16
353	169.40	-54.85	169.19	-64.85
354	174.52	-43.66	175.52	-53.62
355	156.24	-56.73	151.03	-66.34
356	171.47	-51.40	171.92	-61.40

R= 6.96352   DECLINATION= 167.94   INCLINATION= -63.74

ALPHA= 4.72   DELTA= 5.85   KAPPA= 164.47

PLAT= 81.56   PLONG=-211.24   DELP = 5.95

DECLM= -7.49   STLAT= 45.85   STLONG=-122.40



77-38B, 150 ØE

FISHER ON SAMPLE DIRECTIONS

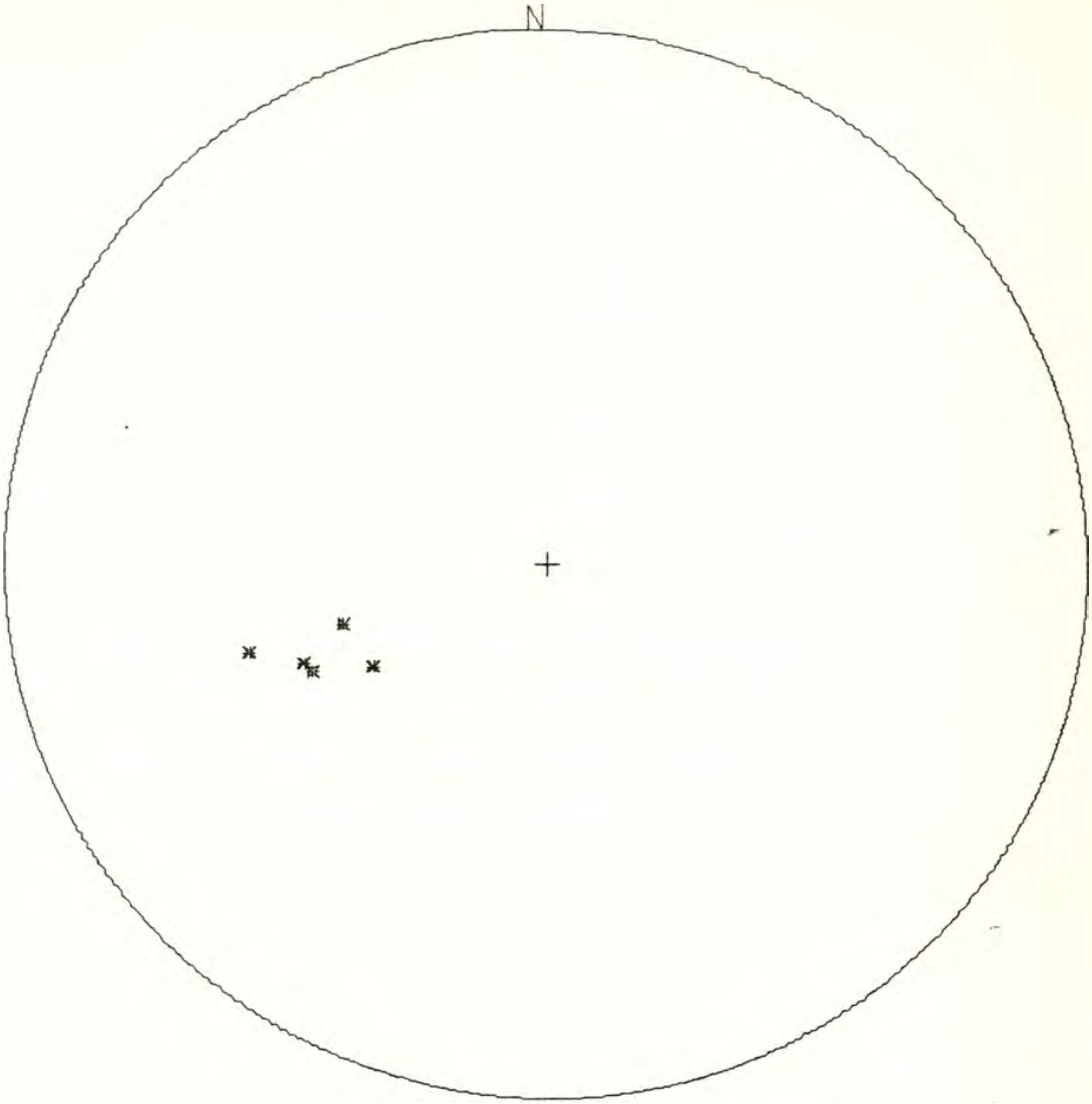
77-39B, NRM E. FORK LEWIS RV 4

SAMPLE NUMBER	DECLINATION	INCLINATION
357	247.43	-49.89
358	253.17	-42.30
359	253.42	-57.86
360	238.98	-59.36
361	245.13	-50.59

R= 4.96356 DECLINATION= 247.98 INCLINATION= -52.12

ALPHA= 7.34 DELTA= 6.92 KAPPA= 109.77

SITE LATITUDE= 45.87 SITE LONGITUDE=-122.43



77-39B. NRM E. FØRK LEWIS RV 4

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-39B, 300 OE

DIP AZIMUTH = 310.0   DIP ANGLE = 12.0

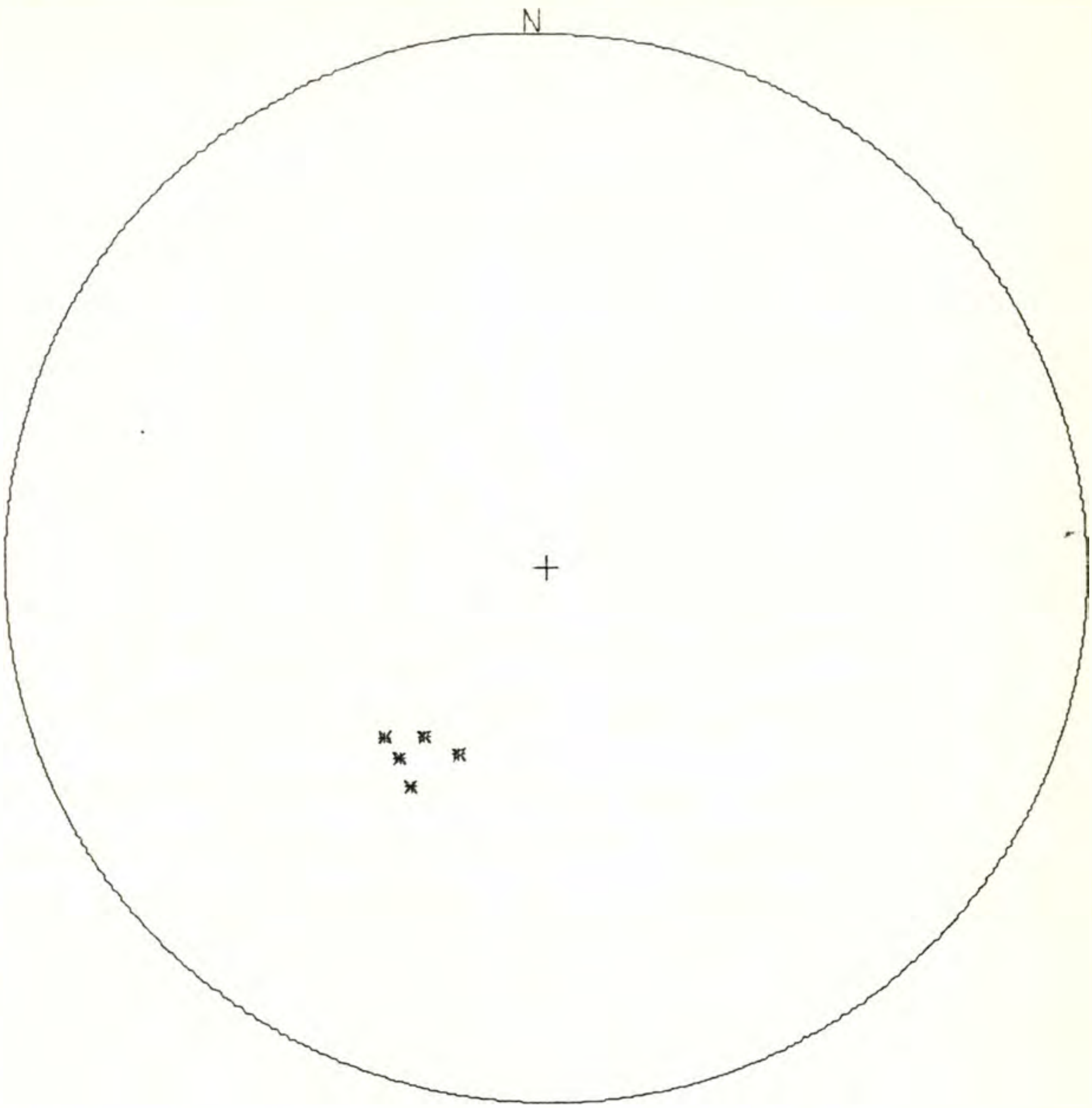
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
357	226.25	-50.65	211.58	-50.42
358	239.10	-51.75	223.41	-54.12
359	234.79	-57.08	215.77	-58.20
360	225.28	-59.57	205.15	-58.55
361	233.22	-52.11	217.44	-53.24

R= 4.98373   DECLINATION= 214.82   INCLINATION= -55.06

ALPHA= 4.89   DELTA= 4.62   KAPPA= 245.90

PLAT= 61.95   PLONG= -23.38   DELP = 4.93

DECLM= -6.94   STLAT= 45.87   STLONG=-122.43



77-39B, 300 OE

FISHER ON SAMPLE DIRECTIONS

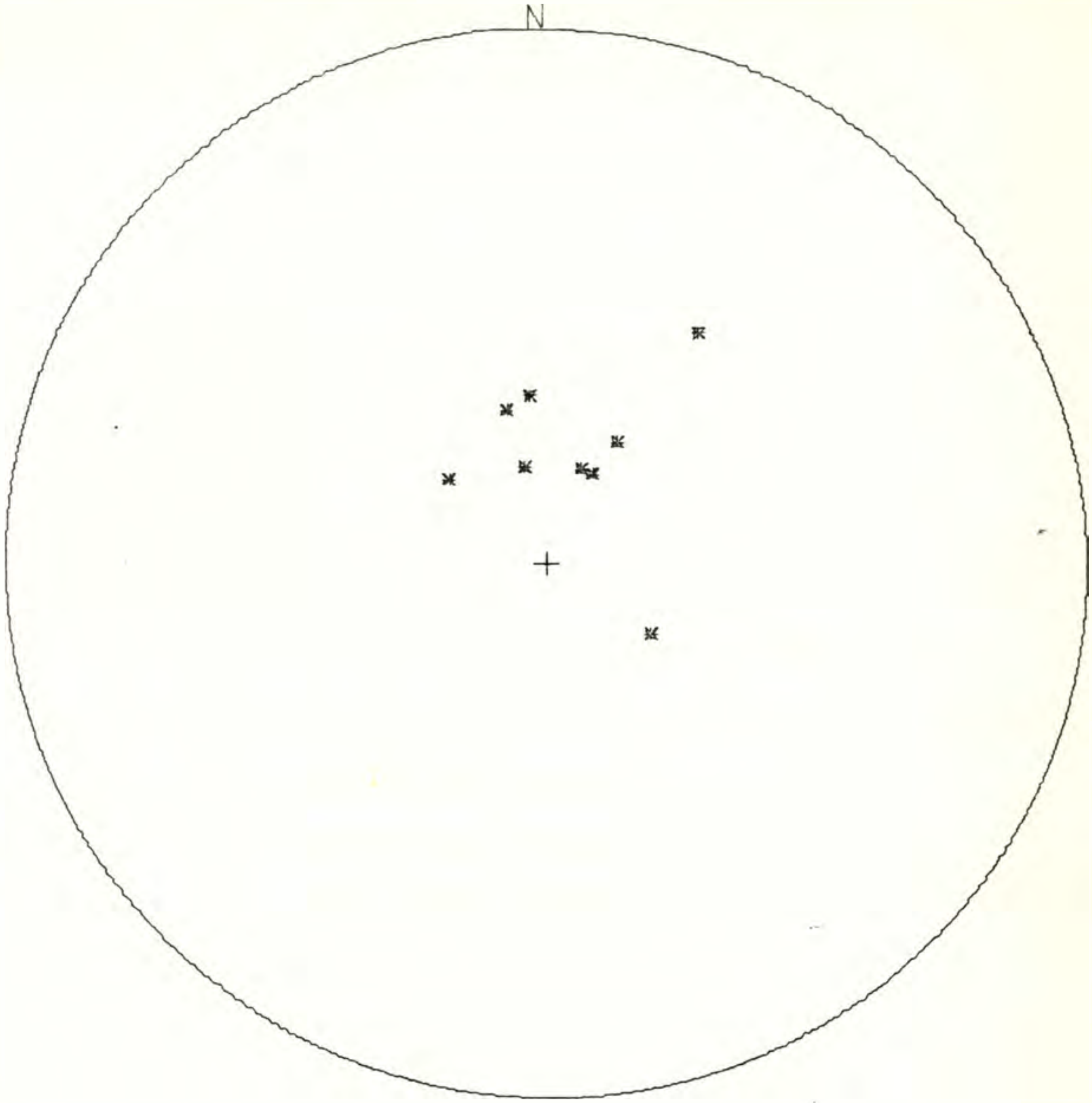
77-40B, NRM E. FORK LEWIS RV 5

SAMPLE NUMBER	DECLINATION	INCLINATION
362	354.77	64.04
363	347.93	74.92
364	27.10	74.66
365	19.89	74.60
366	29.85	68.56
367	33.08	47.26
368	346.22	65.87
369	124.71	71.09
370	311.80	70.70

R= 8.64936 DECLINATION= 13.34 INCLINATION= 72.76

ALPHA= 11.01 DELTA= 16.05 KAPPA= 22.82

SITE LATITUDE= 45.86 SITE LONGITUDE=-122.42



77-40B. NRM E. FØRK LEWIS RV 5

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-40B, 50 OE

DIP AZIMUTH = 165.0   DIP ANGLE = 16.0

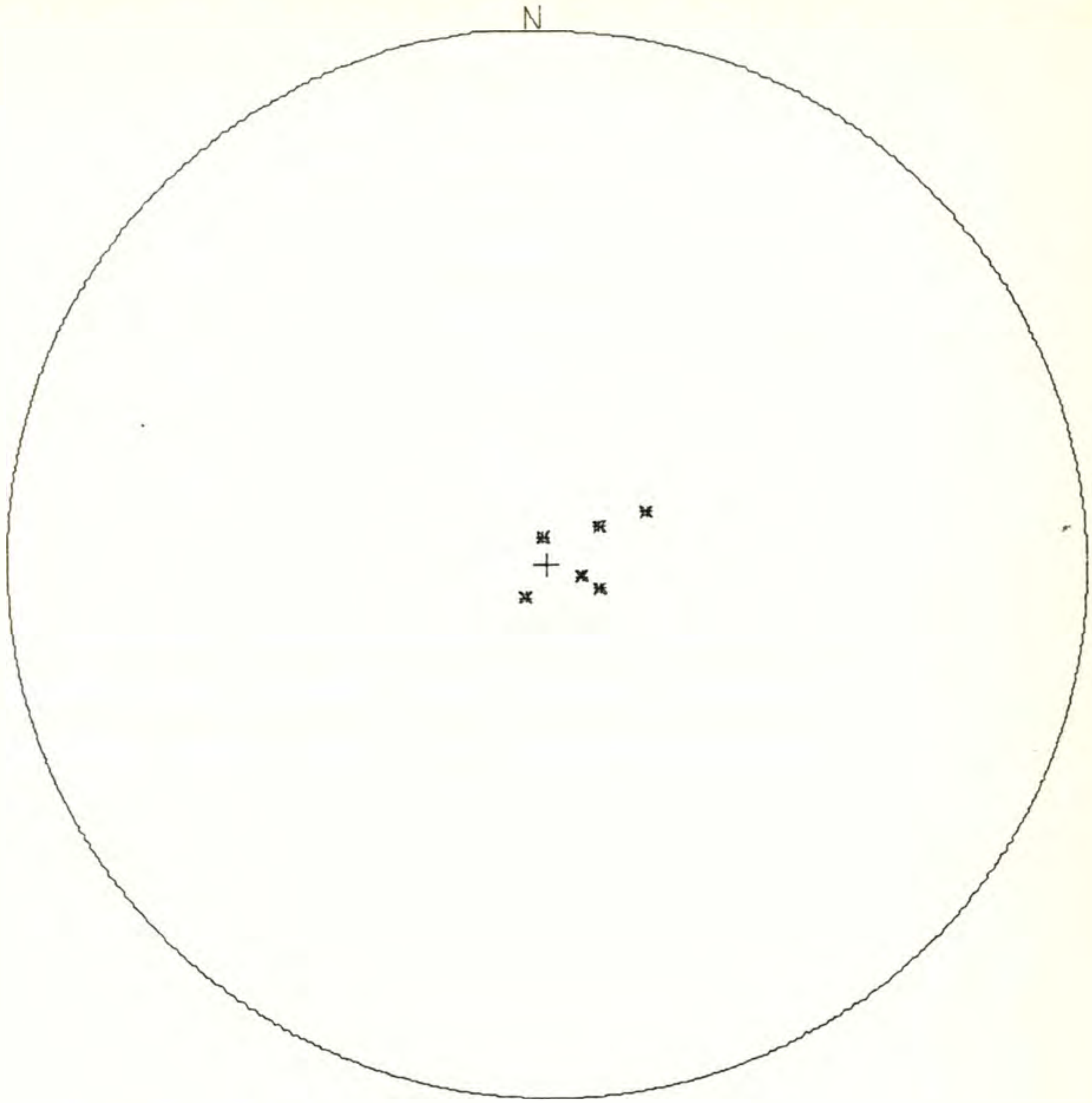
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
362	26.14	64.26	61.97	72.95
364	18.27	77.54	113.97	81.24
365	5.17	76.33	108.82	84.37
366	346.87	69.85	353.85	85.81
368	10.57	68.43	53.52	80.18
370	325.13	77.41	210.84	84.07

R= 5.94542   DECLINATION= 77.12   INCLINATION= 84.38

ALPHA= 7.04   DELTA= 7.73   KAPPA= 91.61

PLAT= 47.23   PLONG=-106.34   DELP = 13.68

DECLM= 13.88   STLAT= 45.86   STLONG=-122.42



77-40B, 50 OE

FISHER ON SAMPLE DIRECTIONS

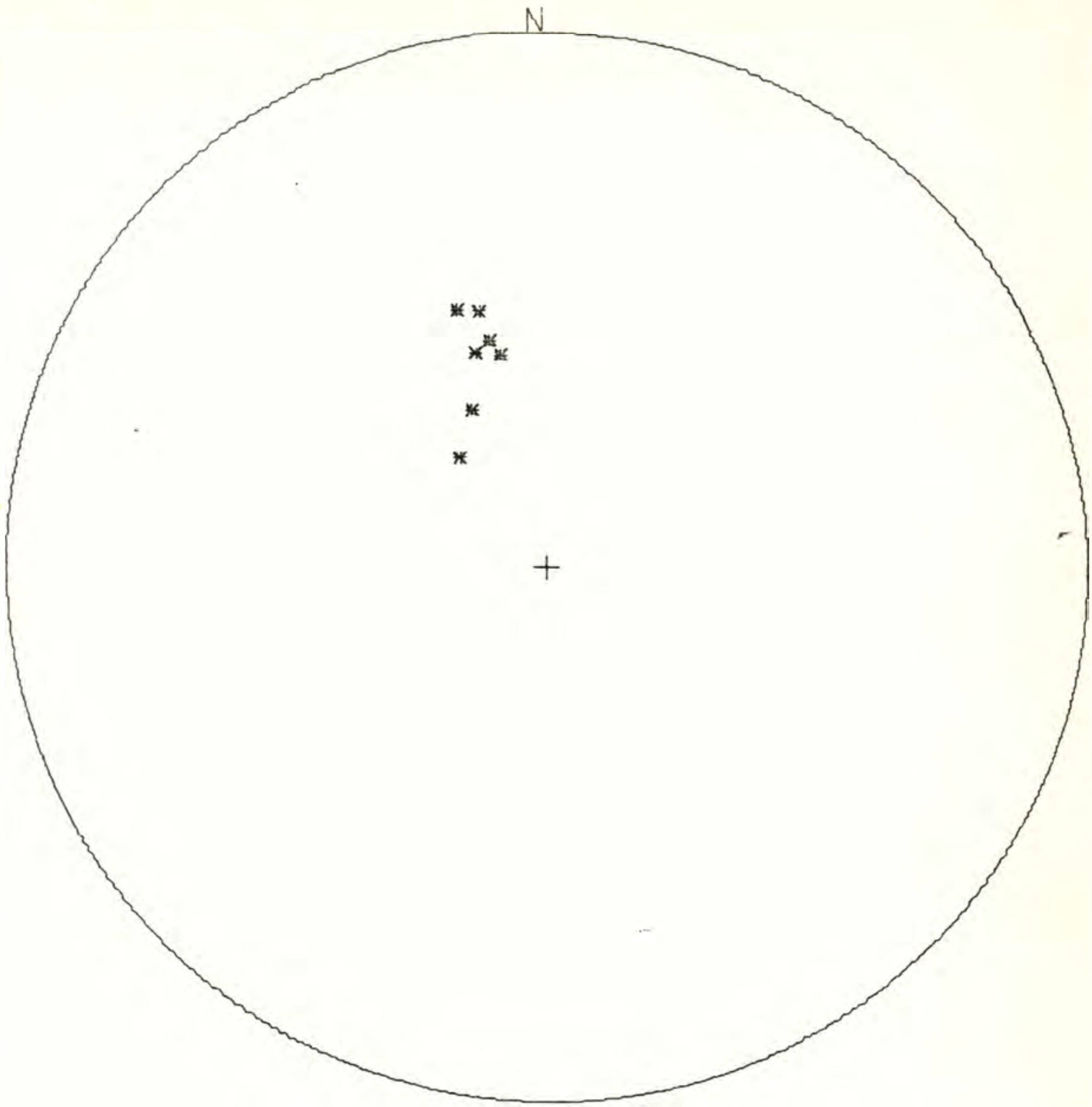
77-41B, NRM WASHOGAL RIVER 1

SAMPLE NUMBER	DECLINATION	INCLINATION
371	342.35	55.37
372	335.19	63.47
373	345.74	49.14
374	346.36	53.99
375	322.47	68.86
376	348.26	56.57
377	341.40	47.91

R= 6.93218 DECLINATION= 341.55 INCLINATION= 56.67

ALPHA= 6.45 DELTA= 7.98 KAPPA= 88.46

SITE LATITUDE= 45.63 SITE LONGITUDE=-122.32



77-41B, NRM WASHOGAL RIVER 1

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-41B, 150 OE

DIP AZIMUTH = 75.0 DIP ANGLE = 26.0

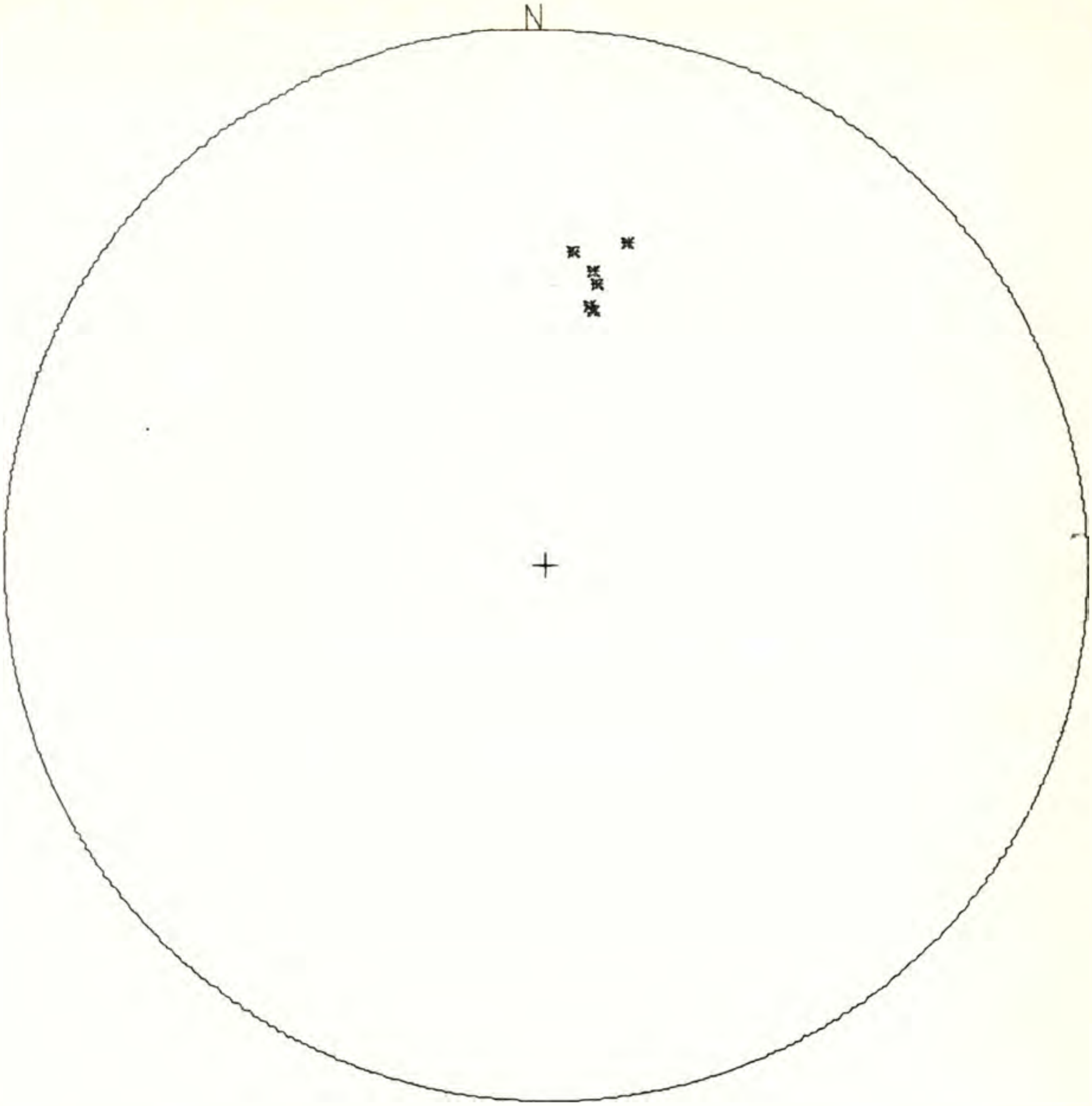
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
371	341.16	50.69	10.47	45.56
372	336.95	54.33	11.09	49.99
373	351.73	46.12	14.47	37.75
375	342.14	48.77	9.51	43.66
376	337.09	53.26	10.08	49.14
377	340.94	44.68	5.34	40.85

R= 5.97929 DECLINATION= 10.17 INCLINATION= 44.53

ALPHA= 4.32 DELTA= 4.76 KAPPA= 241.40

PLAT= 68.93 PLONG= 31.53 DELP = 3.42

DECLM= 5.44 STLAT= 45.63 STLONG=-122.32



77-41B, 150 OE

FISHER ON SAMPLE DIRECTIONS

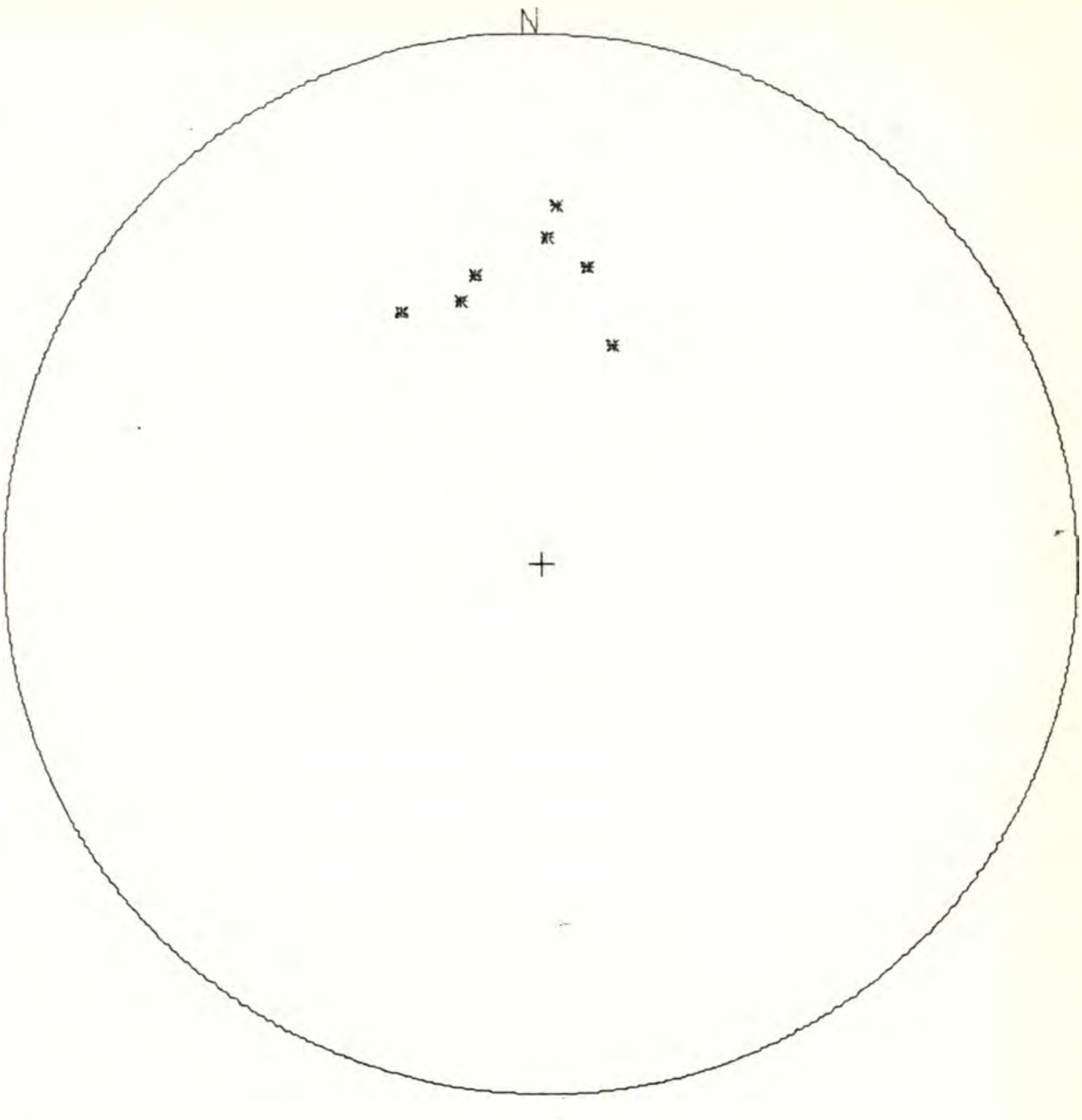
77-42B, NRM WASHOGAL RIVER 2

SAMPLE NUMBER	DECLINATION	INCLINATION
378	343.60	47.10
379	347.68	43.55
380	2.82	32.88
381	331.67	45.14
382	18.17	54.26
383	1.33	38.42
384	9.13	42.75

R= 6.84516 DECLINATION= 356.21 INCLINATION= 44.35

ALPHA= 9.82 DELTA= 12.07 KAPPA= 38.75

SITE LATITUDE= 45.62 SITE LONGITUDE=-122.33



77-42B, NRM WASHOGAL RIVER 2

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-42B, 150 OE

DIP AZIMUTH = 125.0   DIP ANGLE = 20.0

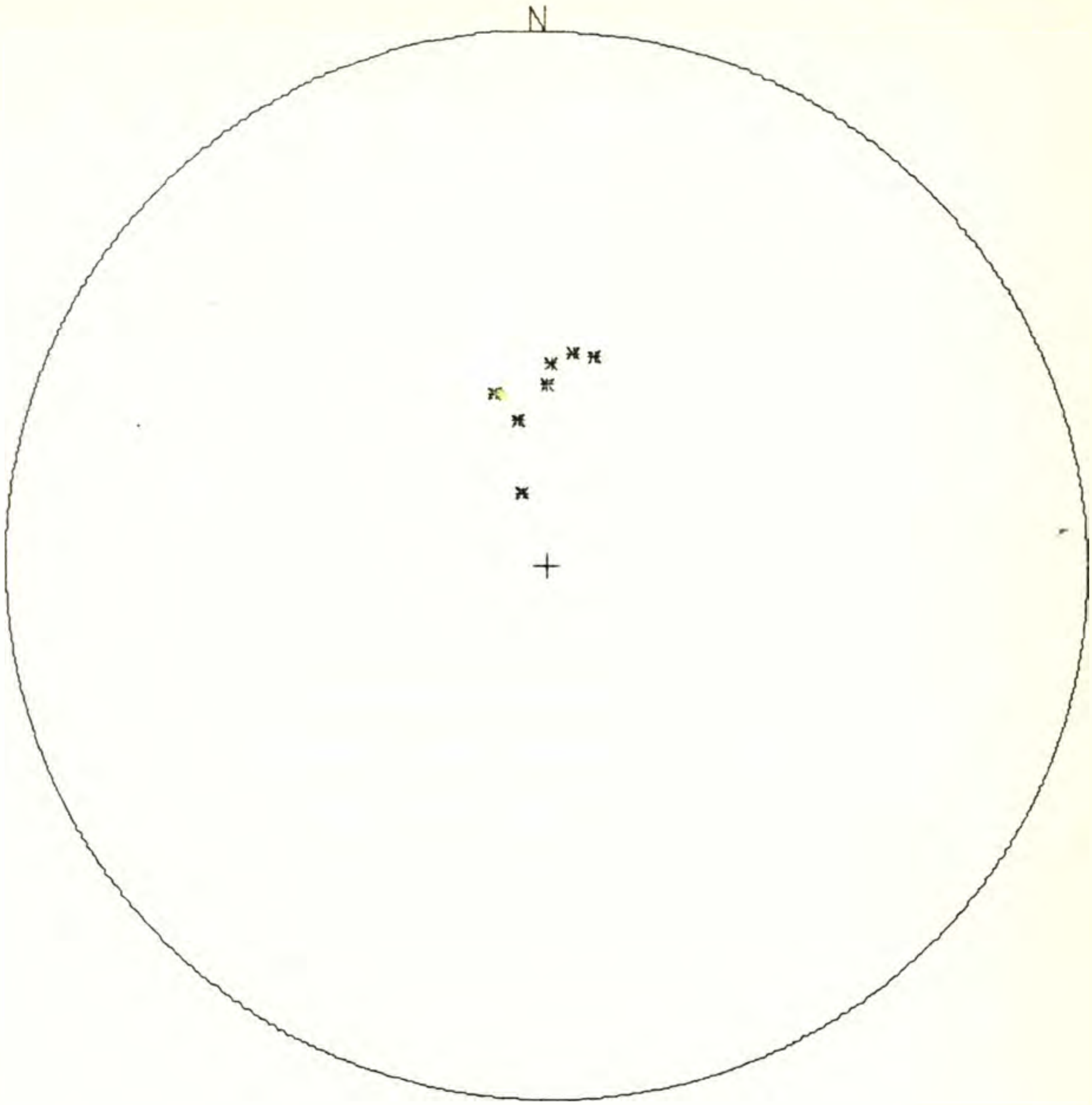
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
378	342.41	44.91	1.28	58.85
379	339.65	47.73	0.09	62.20
380	347.45	44.54	7.14	57.03
381	329.13	45.41	343.68	62.66
382	351.53	45.75	12.85	56.86
383	318.85	60.06	341.92	78.53
384	330.12	50.69	349.43	67.41

R= 6.92345   DECLINATION= 358.88   INCLINATION= 63.73

ALPHA= 6.86   DELTA= 8.48   KAPPA= 78.39

PLAT= 89.18   PLONG= 130.24   DELP = 8.64

DECLM= 10.89   STLAT= 45.62   STLONG=-122.33



77-42B, 150 OE

FISHER ON SAMPLE DIRECTIONS

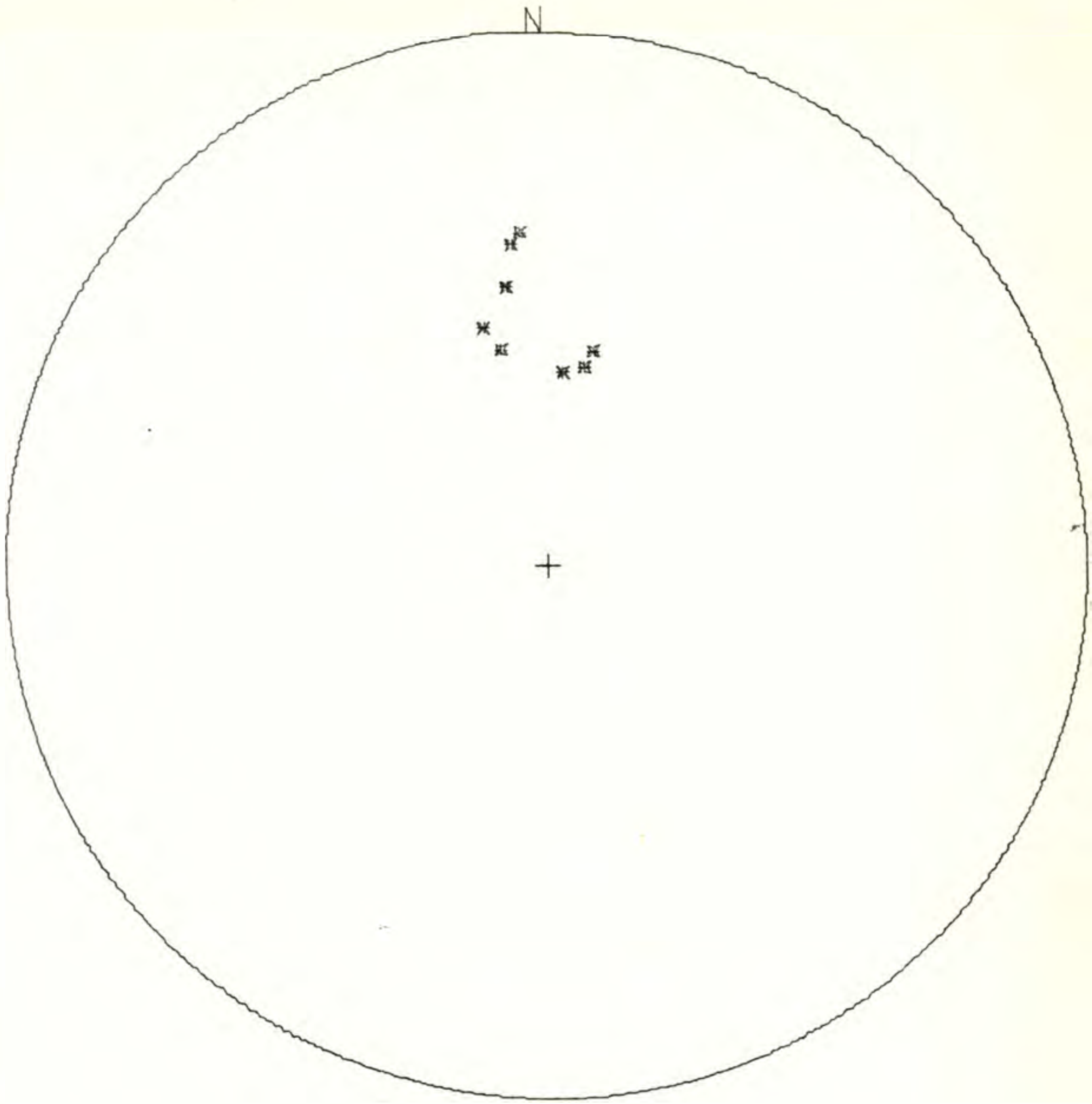
77-43B, NRM WASHOGAL RIVER 3

SAMPLE NUMBER	DECLINATION	INCLINATION
385	12.56	56.18
386	4.73	60.16
387	355.81	37.47
388	348.52	56.05
389	352.21	46.25
390	354.23	39.27
391	10.74	59.02
392	345.55	52.03

R= 7.87864 DECLINATION= 357.26 INCLINATION= 51.16

ALPHA= 7.35 DELTA= 9.99 KAPPA= 57.68

SITE LATITUDE= 45.62 SITE LONGITUDE=-122.33



77-43B, NRM WASHOGAL RIVER 3

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-43B, 100 OE

DIP AZIMUTH = 125.0 DIP ANGLE = 20.0

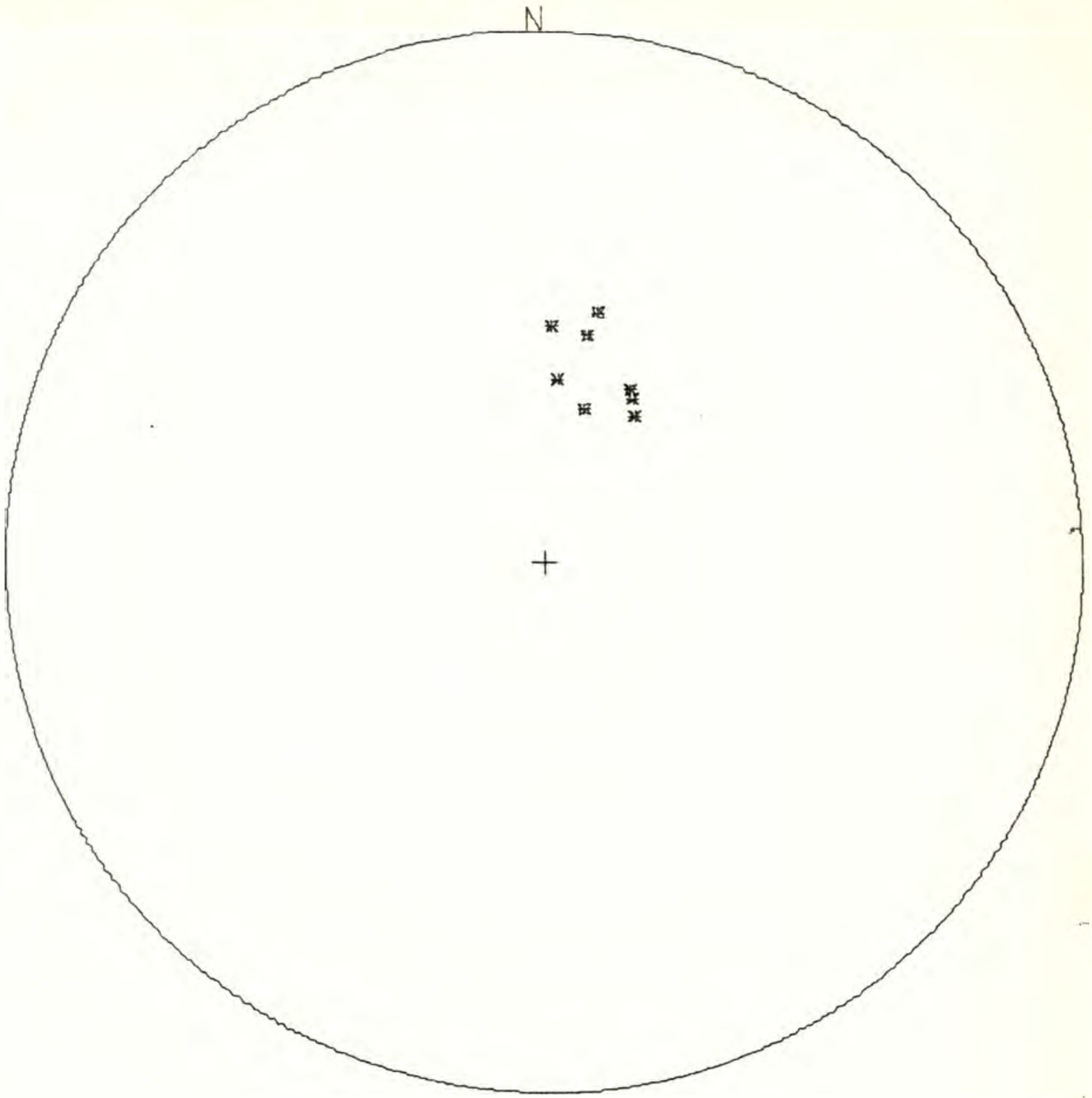
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
385	358.26	52.14	26.33	60.17
386	358.33	56.39	31.67	63.59
387	345.82	39.79	1.89	53.16
388	342.55	48.18	4.24	61.78
389	351.86	42.66	10.84	53.98
390	354.97	39.49	12.16	50.12
391	358.51	53.70	28.39	61.37
392	345.79	53.70	14.38	65.59

R= 7.93211 DECLINATION= 15.46 INCLINATION= 59.14

ALPHA= 5.48 DELTA= 7.47 KAPPA= 103.11

PLAT= 77.33 PLONG= -11.09 DELP = 6.13

DECLM= 8.19 STLAT= 45.62 STLONG=-122.33



77-43B, 100 OE

FISHER ON SAMPLE DIRECTIONS

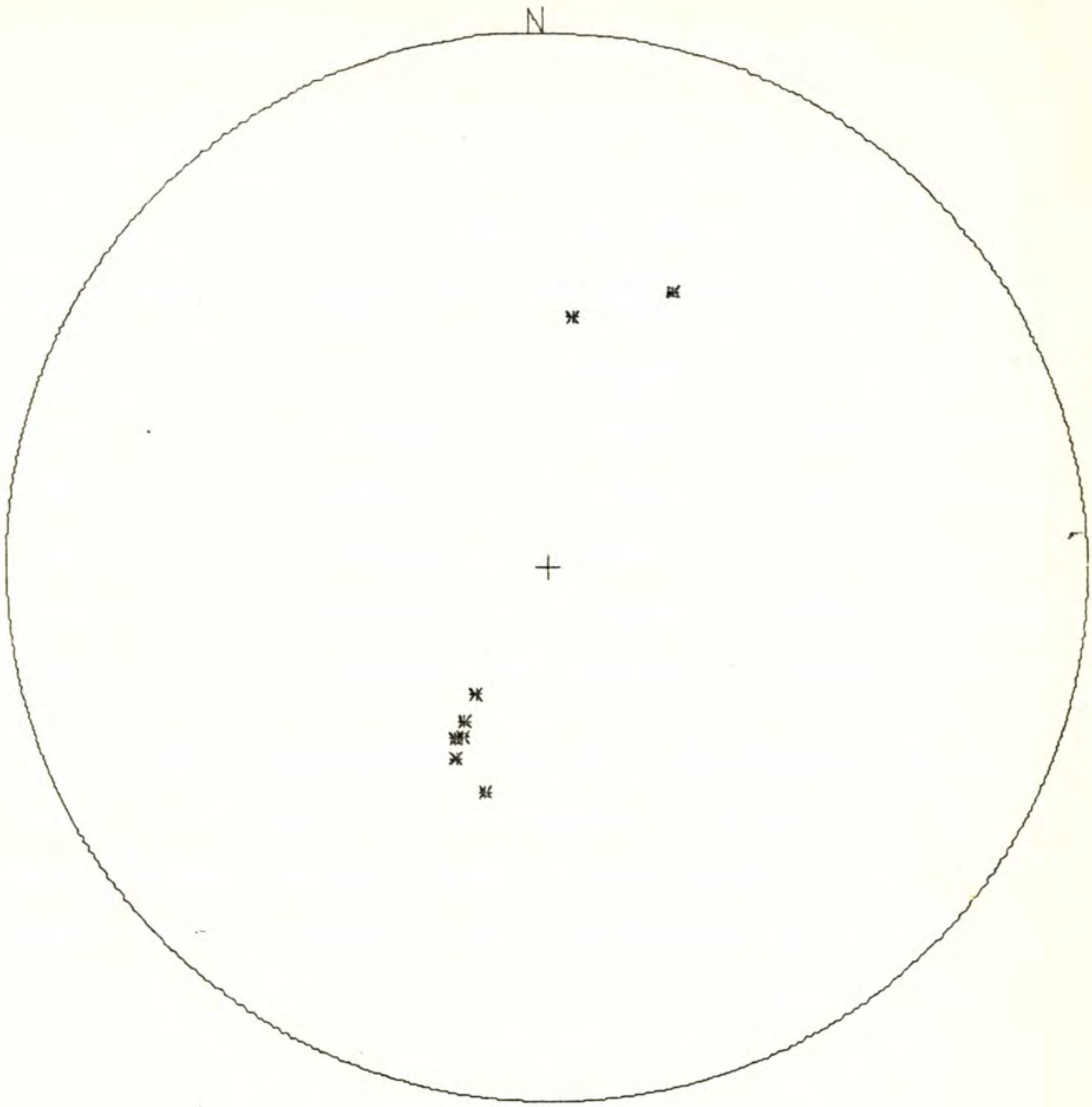
77-44B, NRM GOBLE, ORE.

SAMPLE NUMBER	DECLINATION	INCLINATION
393	205.37	-57.33
394	24.50	42.88
395	209.63	-67.74
396	6.08	51.04
397	195.72	-53.78
398	206.65	-60.94
399	208.26	-63.11
400	208.33	-60.11

R= 4.08486 DECLINATION= 212.71 INCLINATION= -66.60

ALPHA= 60.79 DELTA= 59.30 KAPPA= 1.79

SITE LATITUDE= 46.08 SITE LONGITUDE=-122.88



77-44B. NRM GOBLE, ORE.

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-44B, 300 OE

DIP AZIMUTH = 200.0 DIP ANGLE = 10.0

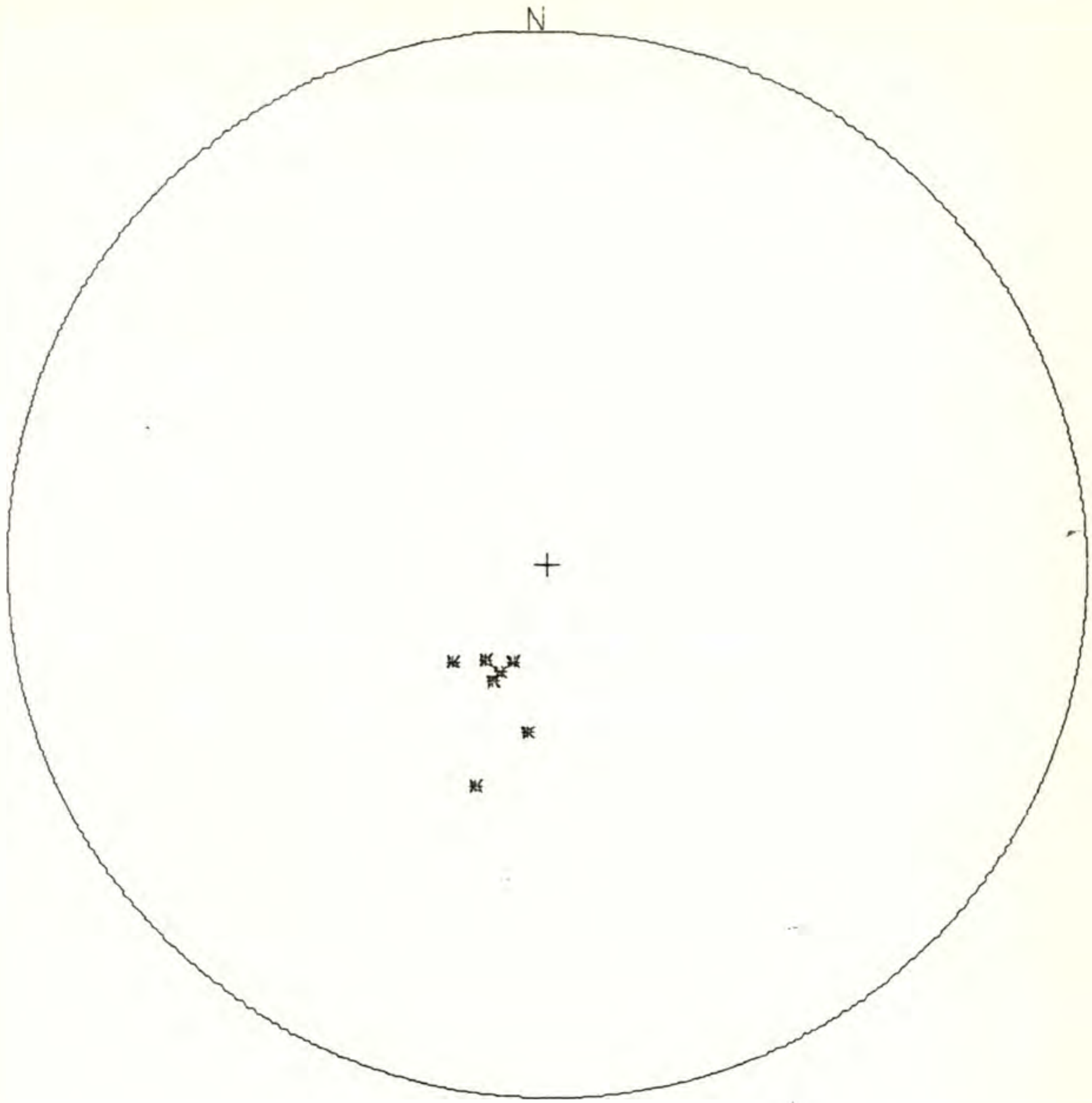
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
393	216.15	-60.15	223.38	-69.58
394	198.19	-44.08	197.78	-54.07
395	207.80	-62.93	212.05	-72.79
397	190.00	-54.39	186.57	-64.19
398	203.11	-60.56	204.59	-70.54
399	199.08	-64.38	198.52	-74.38
400	201.81	-62.24	202.76	-72.23

R= 6.93759 DECLINATION= 202.51 INCLINATION= -68.63

ALPHA= 6.19 DELTA= 7.66 KAPPA= 96.14

PLAT= 74.19 PLONG= -62.87 DELP = 8.85

DECLM=-10.46 STLAT= 46.08 STLONG=-122.88



77-44B. 300 OE

FISHER ON SAMPLE DIRECTIONS

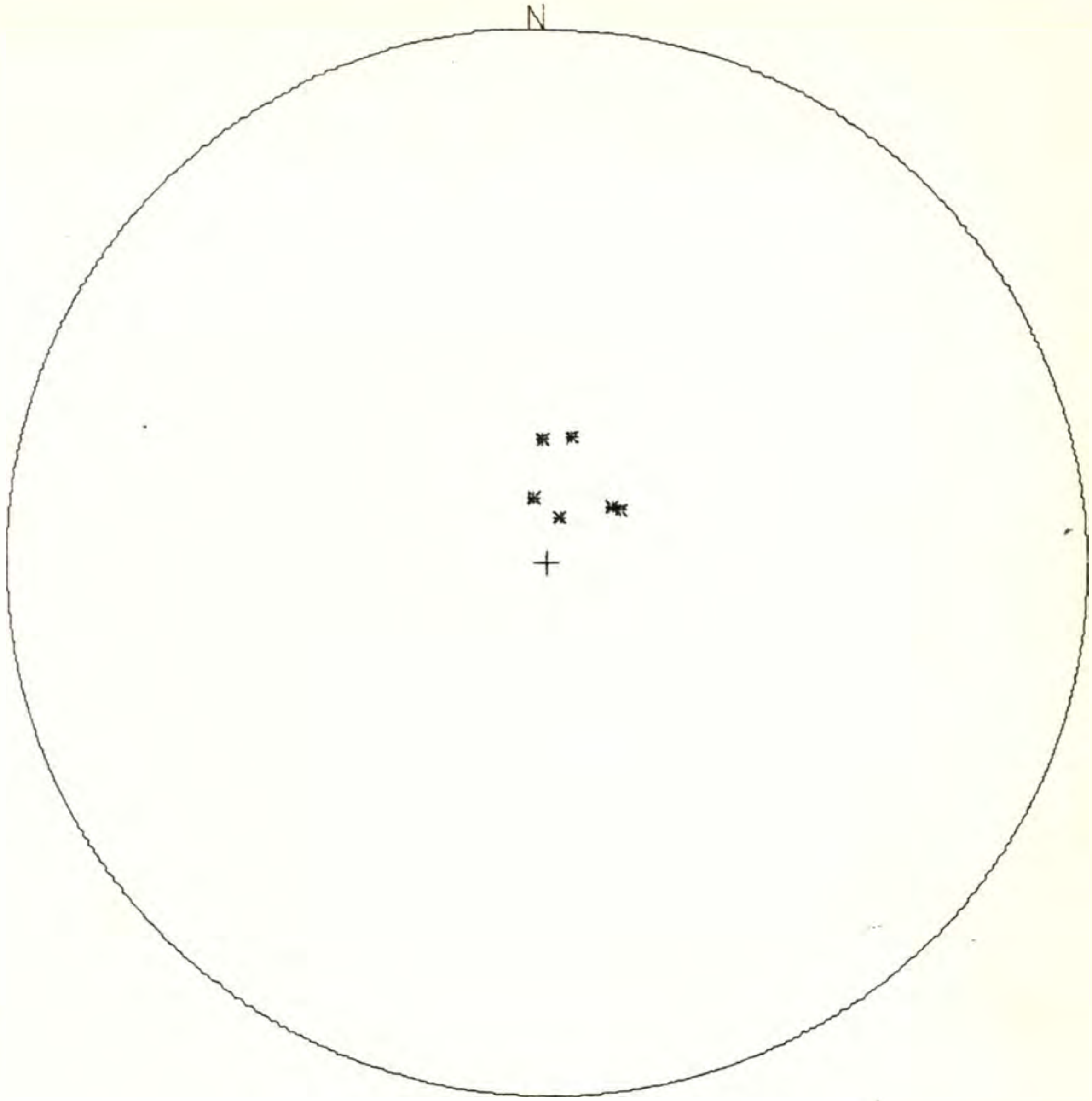
77-45B, NRM TROJAN

SAMPLE NUMBER	DECLINATION	INCLINATION
401	11.57	70.43
402	49.75	76.96
403	54.21	76.31
404	16.86	82.92
405	349.36	79.96
406	358.57	71.06

R= 5.95422 DECLINATION= 19.19 INCLINATION= 77.41

ALPHA= 6.44 DELTA= 7.08 KAPPA= 109.22

SITE LATITUDE= 46.07 SITE LONGITUDE=-122.90



77-45B, NRM TRØJAN

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-45B, 200 OE

DIP AZIMUTH = 242.0   DIP ANGLE = 10.0

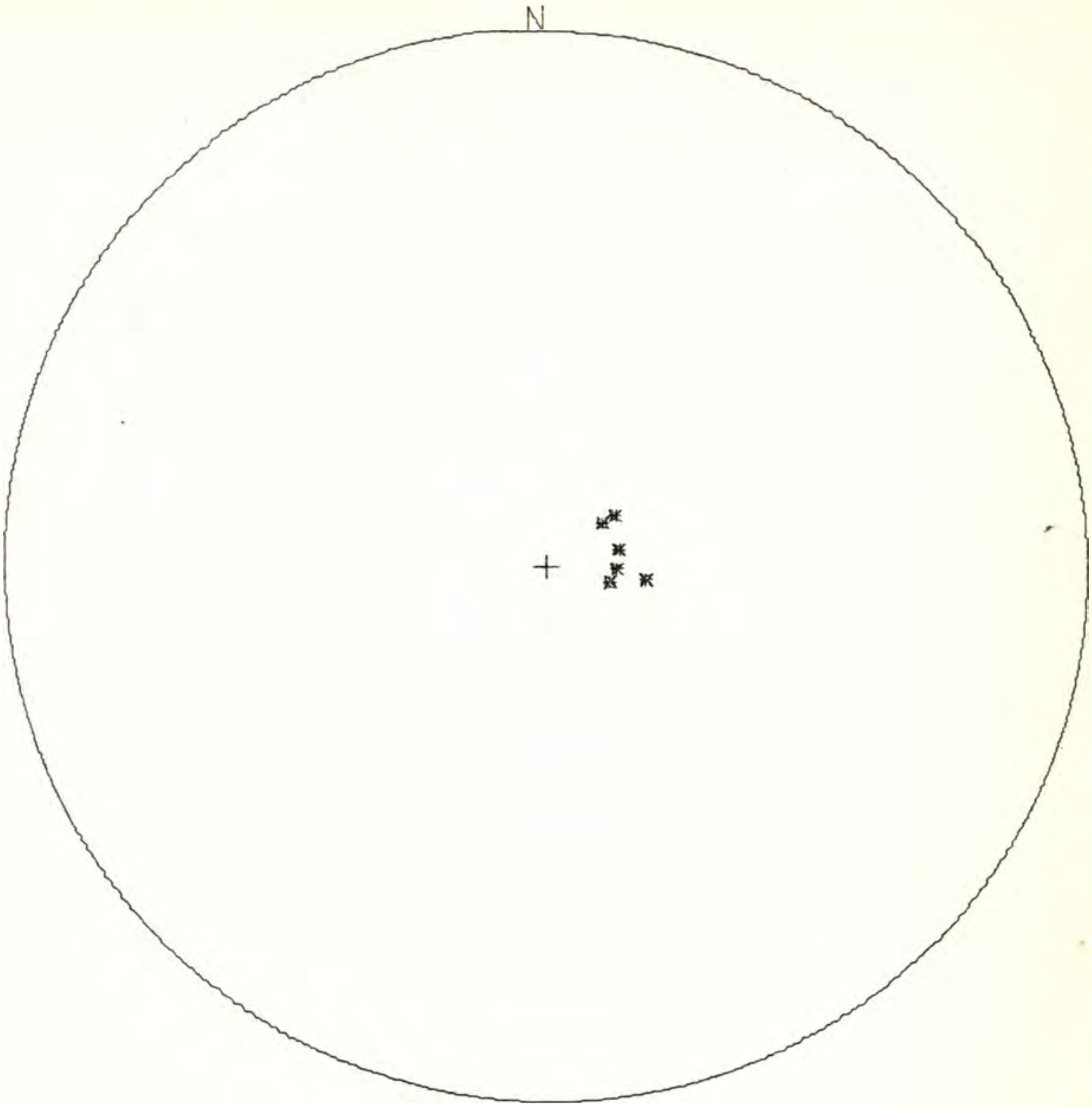
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
401	57.02	69.39	52.51	79.32
402	77.56	70.04	91.68	79.34
403	70.35	68.94	77.51	78.74
404	83.80	66.04	97.35	74.89
405	83.02	71.49	103.84	80.17
406	57.21	67.02	53.69	76.96

R= 5.98229   DECLINATION= 79.51   INCLINATION= 78.94

ALPHA= 3.99   DELTA= 4.40   KAPPA= 282.36

PLAT= 45.79   PLONG= -92.00   DELP = 7.19

DECLM= 7.58   STLAT= 46.07   STLONG=-122.90



77-45B, 200 OE

FISHER ON SAMPLE DIRECTIONS

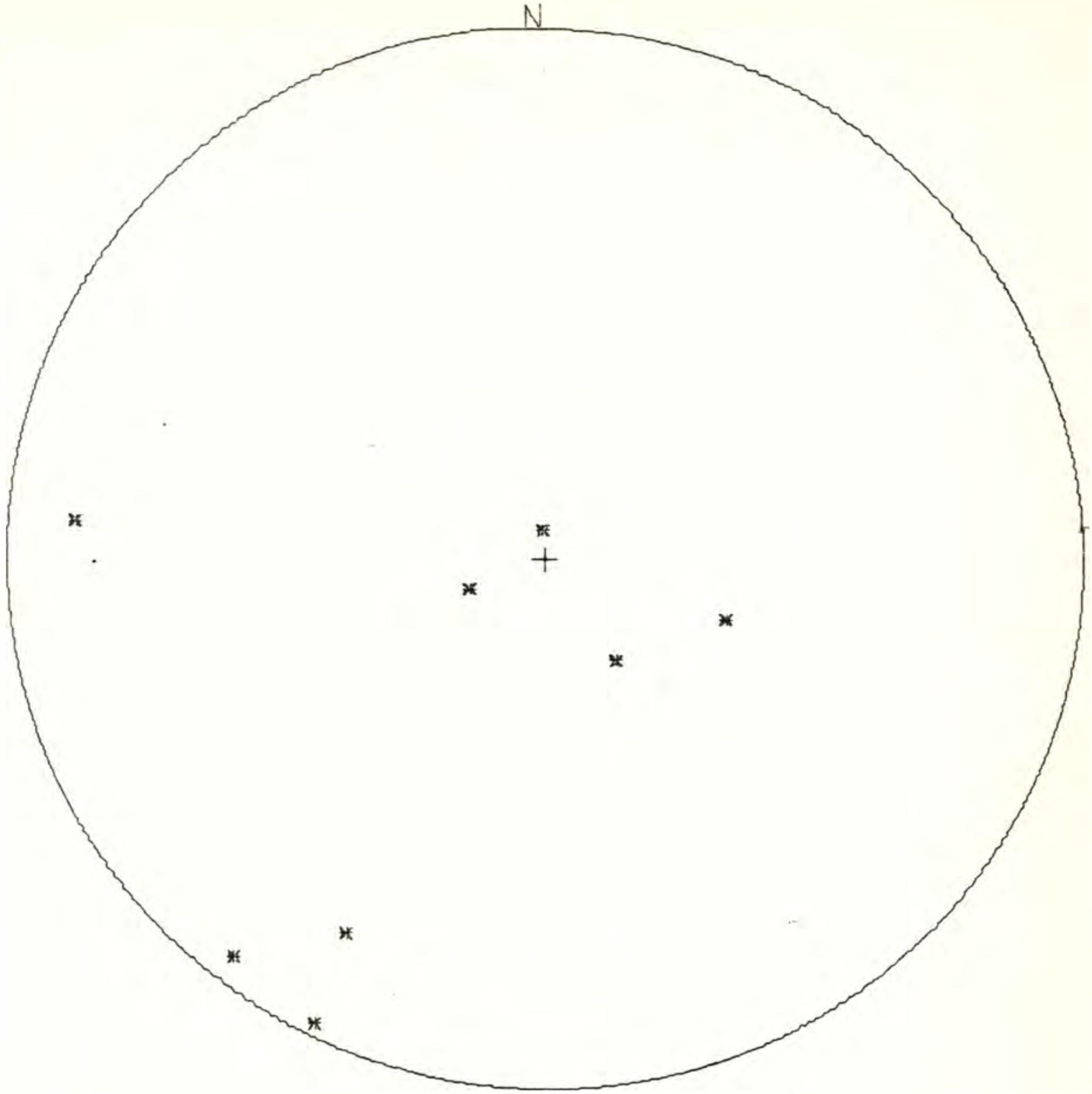
77-46B, NRM COLUMBIA RV W. 1

SAMPLE NUMBER	DECLINATION	INCLINATION
407	108.94	60.88
408	207.79	-21.51
409	206.30	-2.90
410	217.83	-5.74
411	145.24	71.04
412	356.82	85.41
413	247.98	77.89
414	274.82	-13.60

R= 4.62443 DECLINATION= 215.21 INCLINATION= 41.12

ALPHA= 52.40 DELTA= 54.69 KAPPA= 2.07

SITE LATITUDE= 45.98 SITE LONGITUDE=-122.88



77-46B, NRM COLUMBIA RV W. 1

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-46B, 250 OE

DIP AZIMUTH = 240.0   DIP ANGLE = 10.0

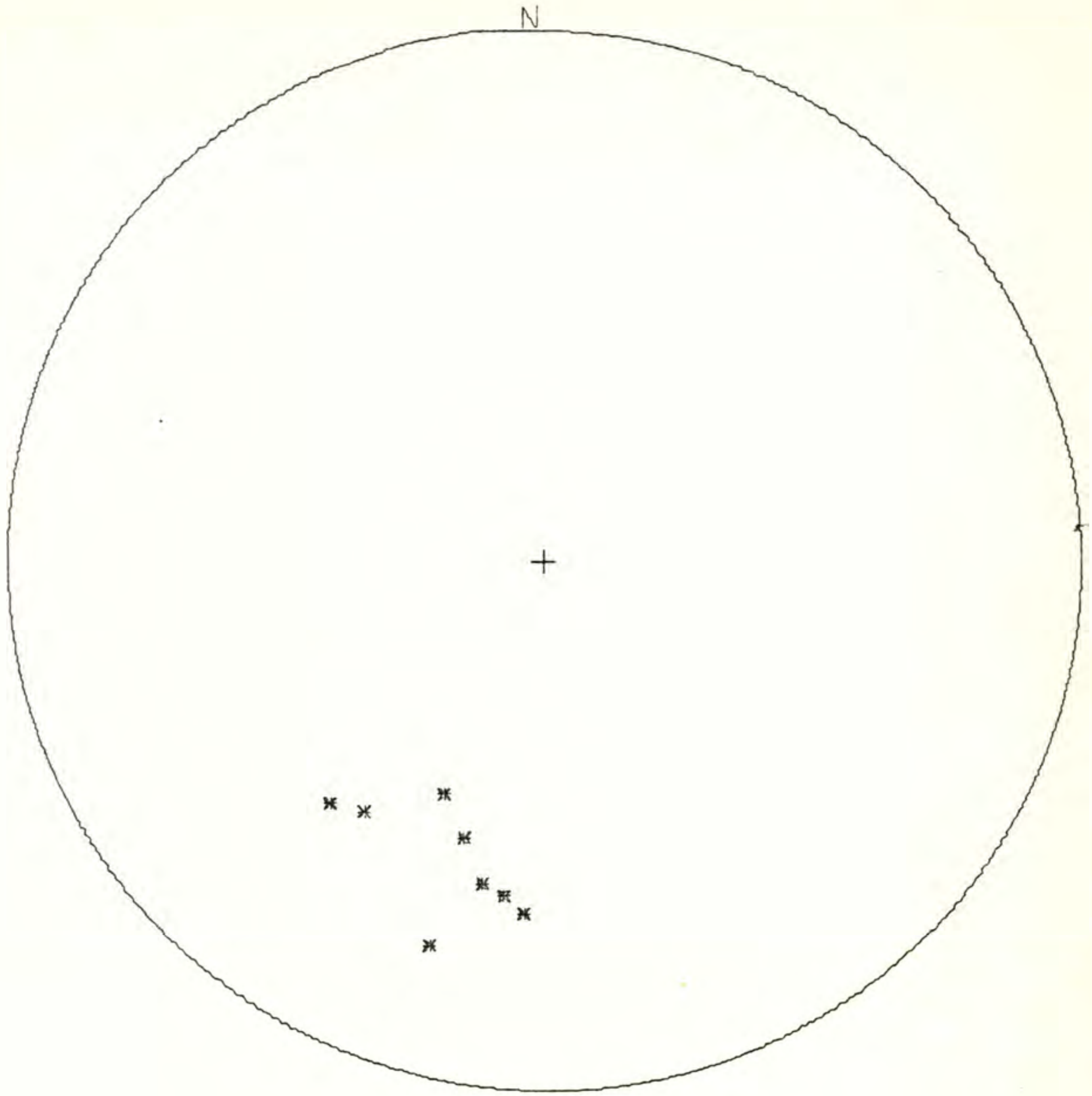
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
407	201.99	-37.09	196.31	-44.67
408	196.13	-31.05	191.14	-37.97
409	188.27	-27.76	183.44	-33.63
410	192.27	-30.18	187.19	-36.59
411	199.29	-17.84	196.64	-25.28
412	223.50	-29.81	221.42	-39.35
413	209.05	-42.30	203.16	-50.62
414	218.44	-32.35	215.49	-41.56

R= 7.82531   DECLINATION= 198.88   INCLINATION= -39.39

ALPHA= 8.86   DELTA= 12.00   KAPPA= 40.07

PLAT= 61.81   PLONG= 17.81   DELP = 6.34

DECLM=-10.60   STLAT= 45.98   STLONG=-122.88



77-46B, 250 OE

FISHER ON SAMPLE DIRECTIONS

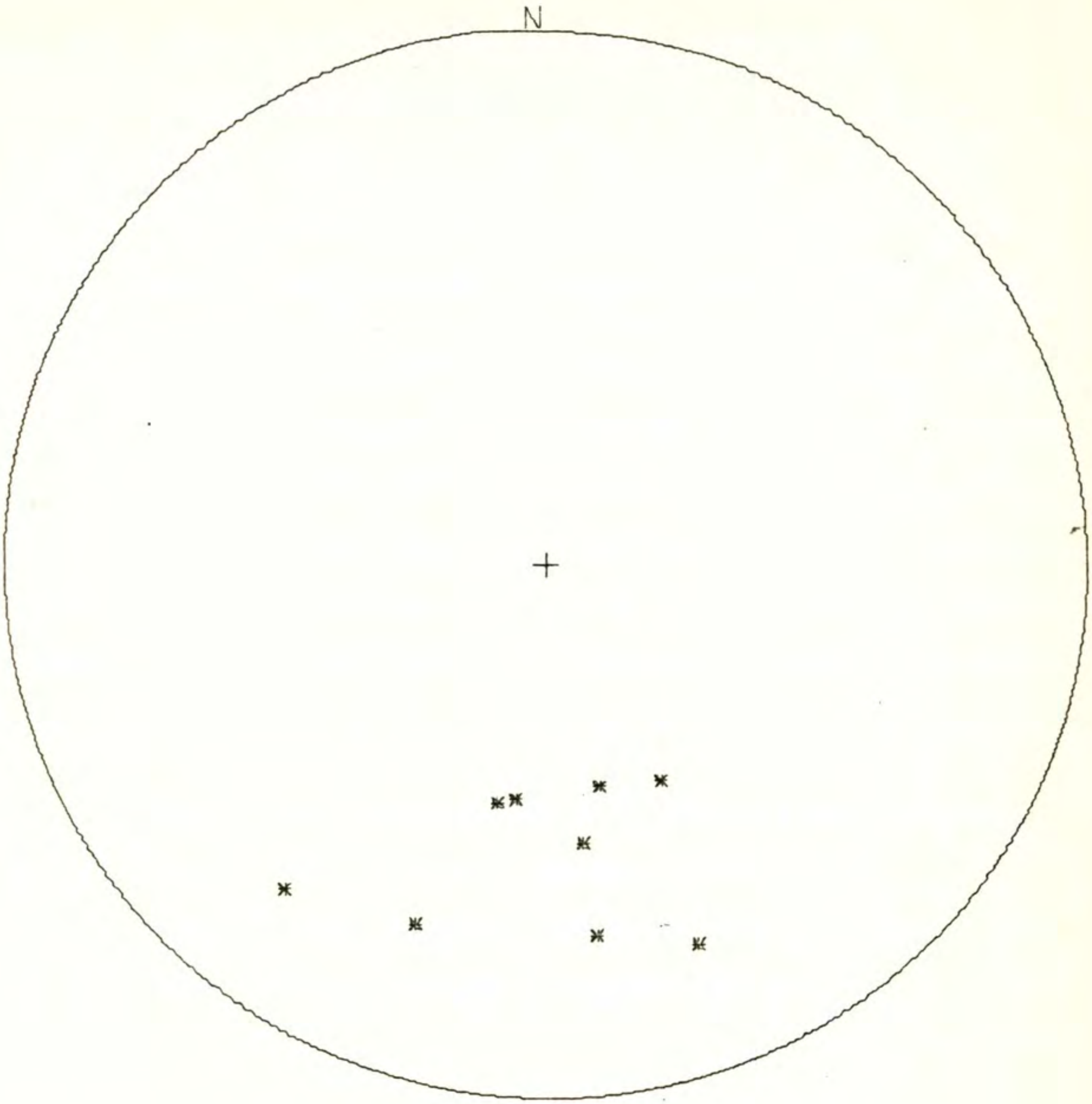
77-47B, NRM COLUMBIA RV W. 2

SAMPLE NUMBER	DECLINATION	INCLINATION
416	191.79	-52.43
417	152.67	-52.50
418	200.07	-29.17
419	218.70	-23.63
420	166.90	-54.93
421	173.07	-46.26
422	187.57	-53.68
423	172.69	-30.58
424	159.01	-24.62

R= 8.46091 DECLINATION= 181.35 INCLINATION= -42.78

ALPHA= 13.82 DELTA= 19.93 KAPPA= 14.84

SITE LATITUDE= 46.02 SITE LONGITUDE=-122.88



77-47B. NRM COLUMBIA RV W. 2

TECTONIC CORRECTION ON SAMPLE DIRECTIONS

POLE ON SITE MEAN

77-47B, 300 OE

DIP AZIMUTH = 210.0 DIP ANGLE = 11.0

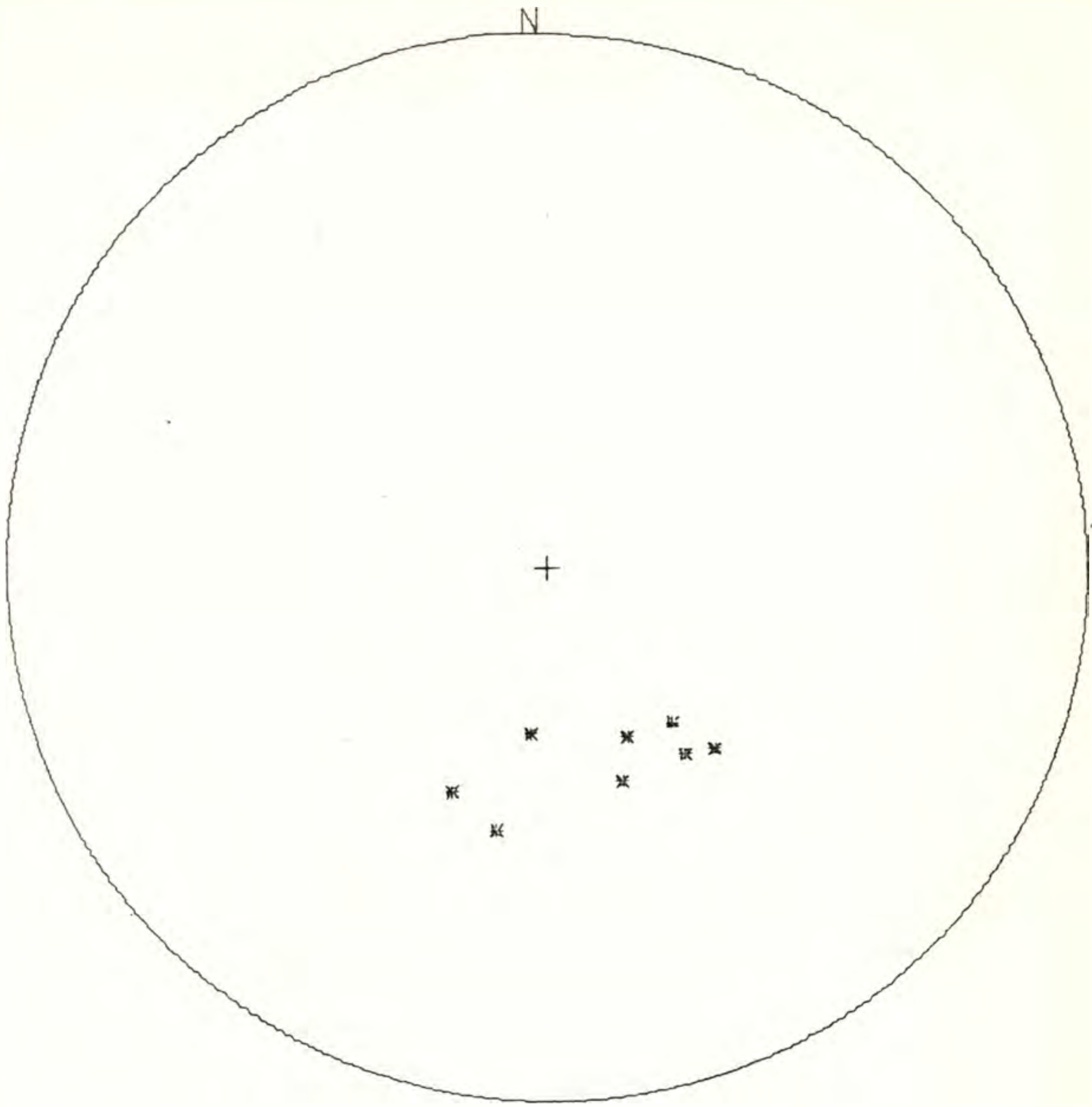
SAMPLE NUMBER	DECLINATION	INCLINATION	SDEC	SINC
416	192.48	-54.10	185.88	-64.40
417	156.78	-54.11	142.03	-59.57
418	194.39	-37.80	191.35	-48.32
419	204.55	-41.53	203.30	-52.47
420	168.47	-53.98	155.47	-61.40
421	170.86	-47.28	161.31	-55.24
422	156.40	-48.88	144.33	-54.48
423	150.17	-47.72	138.15	-52.26

R= 7.76356 DECLINATION= 165.45 INCLINATION= -58.34

ALPHA= 10.35 DELTA= 13.96 KAPPA= 29.61

PLAT= 77.23 PLONG= 119.16 DELP = 11.33

DECLM=-15.31 STLAT= 46.02 STLONG=-122.88



77-47B, 300 OE