

TRIP B-2

GEOLOGY OF THE HOLDERNESS QUADRANGLE

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Introduction

The Holderness Quadrangle in central New Hampshire lies astride or slightly to the west of the projected axis of the Merrimack synclinorium. This trip illustrates problems encountered in attempting to define lithostratigraphic markers in the pelitic schists of the area, and demonstrates that the metasediments have passed through at least two, and possibly three phases of folding. Thin sheets of Winnepesaukee Quartz Diorite and Kinsman Quartz Monzonite in the northeastern portion of the quadrangle appear to play a significant role in the overall structural interpretation.

Lithology

The Littleton formation (D1) is the principal metasedimentary unit in central New Hampshire. It consists chiefly of gray quartz-biotite schists, often with garnet and/or sillimanite. Graded sequences consisting of alternating quartzitic and pelitic layers up to 4 or 5 cm. thick are sometimes seen, as well as a similar, though somewhat thinner compositional banding with no obvious grading. Coticule bands and calc-silicate boudins are present, but the latter are relatively rare. The weathered surface is generally gray, except where pyrrhotite or pyrite is present, when the surface takes on a rusty color. The latter phase of the Littleton is sometimes difficult to distinguish from the Clay Brook member.

The Clay Brook member (D1c) is the only mappable sub-unit of the Littleton observed to date in the Holderness quadrangle. It is distinguished by very rusty weathering, and the presence of abundant sulfides and graphite. Typical lithologies are sulfidic, graphitic quartz muscovite schist, sometimes with biotite; and a hard, sulfide-rich, quartz-feldspar granulite. Garnet and sillimanite are rare.

The Kinsman Quartz Monzonite (kqm) is characterized by K-feldspar megacrysts up to 10 cm. or more in length. These commonly have discontinuous myrmekitic rims, and are frequently rounded or tapered by shearing. The groundmass of quartz, biotite, and plagioclase often appears cataclastic in thin section. The Kinsman-Littleton contact is complex, and the contact zone (Dlk) can be best described as a lit-par-lit injection of Kinsman along the foliation of the Littleton schist.

The Winnepesaukee Quartz Diorite (qd) is a well foliated, homogeneous, medium-grained, quartz-feldspar-biotite gneiss, and is generally considered to be equivalent to the Bethlehem gneiss.

The Concord granite (big) is a generally non-foliated homogeneous, light gray, muscovite-biotite granite.

Structure

Figure 2a shows poles to foliation over the entire area of the Littleton Formation in the Holderness quadrangle. The simplest explanation for the broad girdle pattern is to assume an original, nearly horizontal (axial-plane?) foliation, refolded rather gently around horizontal NW axes to a maximum dip of about 50° , and then isoclinally refolded again about horizontal NE trending axes. Although bedding, where observed, is generally parallel to foliation, minor folds and lineations suggest that this original foliation is axial plane foliation to large recumbent isoclinal folds with NW trending axes.

This picture is complicated by the fact that the distribution of poles to foliation is not uniform throughout the quadrangle, as shown in Figures 2b, 2c, and 2d, corresponding to zones 1, 2, and 3 in the Littleton Formation on Figure 1. Note the essentially vertical nature of the foliation in zone 1, compared with the relatively shallow dips in zone 3. Zone 2 appears to be intermediate. This is interpreted as indicating that the deformation about the NE axes was of about the same intensity as that about the NW axes in zone 3, leading to relatively shallow folds, whereas in zone 1, the folding about NE axes was much more intense, obliterating most of the evidence of earlier folding.

The outcrop pattern of the Clay brook member, along with its foliation pattern suggests that it is a southerly plunging antiform. Unfortunately, this has no stratigraphic significance if an early period of recumbent isoclinal folding is assumed.

The Kinsman Quartz Monzonite and Winnepesaukee Quartz Diorite together form a pluton of batholithic dimensions, even without considering their extension to the east of the Holderness Quadrangle. Gravity measurements by Bean (1953) and Englund (unpublished data) indicate, however, that the maximum thickness of this batholith in the Holderness Quadrangle is from 2 to 4 km. Similar results have been obtained by Clark (cf. Cardigan Pluton Road Log) in the Mt. Kearsage Quadrangle. This, and the generally concordant nature of the contacts suggests that the Kinsman-Winnepesaukee pluton was intruded as a large still-like body, or perhaps formed in situ by the melting of a thick pile or piles of silicic volcanics (Thompson et al., 1968).

Figures 2e and 2f show poles to foliation for the Kinsman and the Winnepesaukee. These foliations are apparently related to the last period of deformation. The cataclastic nature of the deformation in the Kinsman indicates that it had solidified prior to this last period of folding. The Kinsman-Winnepesaukee pluton may have acted as a solid plate during this final state of folding, partially shielding the area in zone 3 from deformation, while intensifying it in zone 1.

The proposed sequence of events in this area may be summarized as follows:

- 1) Deposition of Littleton Formation as turbidites and pelites. Deposition ended in the Lower Devonian, but areal relations suggest that some of the Littleton(?) may be Silurian or older. The position of the Clay Brook member with respect to the Littleton is uncertain.
- 2) Isoclinal recumbent folding about NW trending axes, leading to a prominent horizontal axial plane foliation.
- 3) Intrusion of the Kinsman-Winnepesaukee "sill". Lit-par-lit injection of the Littleton occurs around the edges of the sheet.
- 4) Gentle open folding about NW trending axes. This may have occurred before intrusion of the Kinsman-Winnepesaukee sheet.

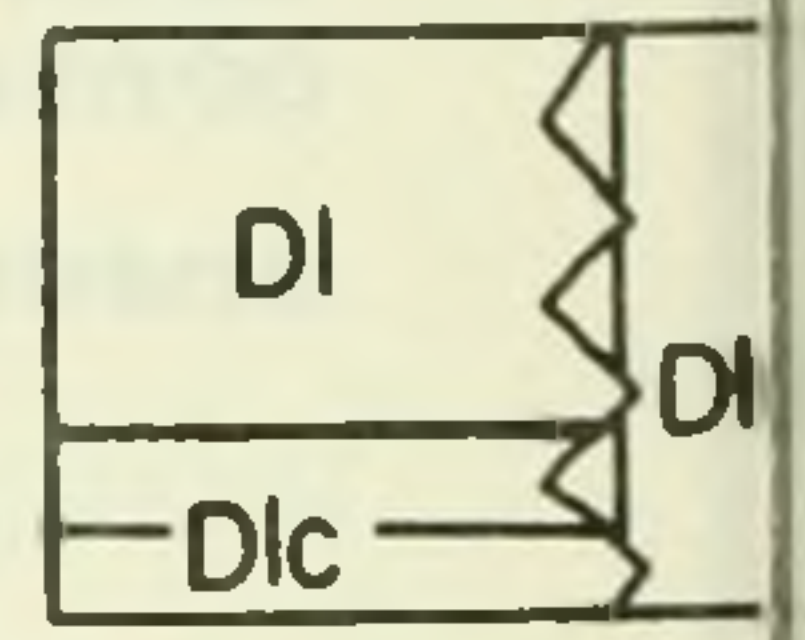
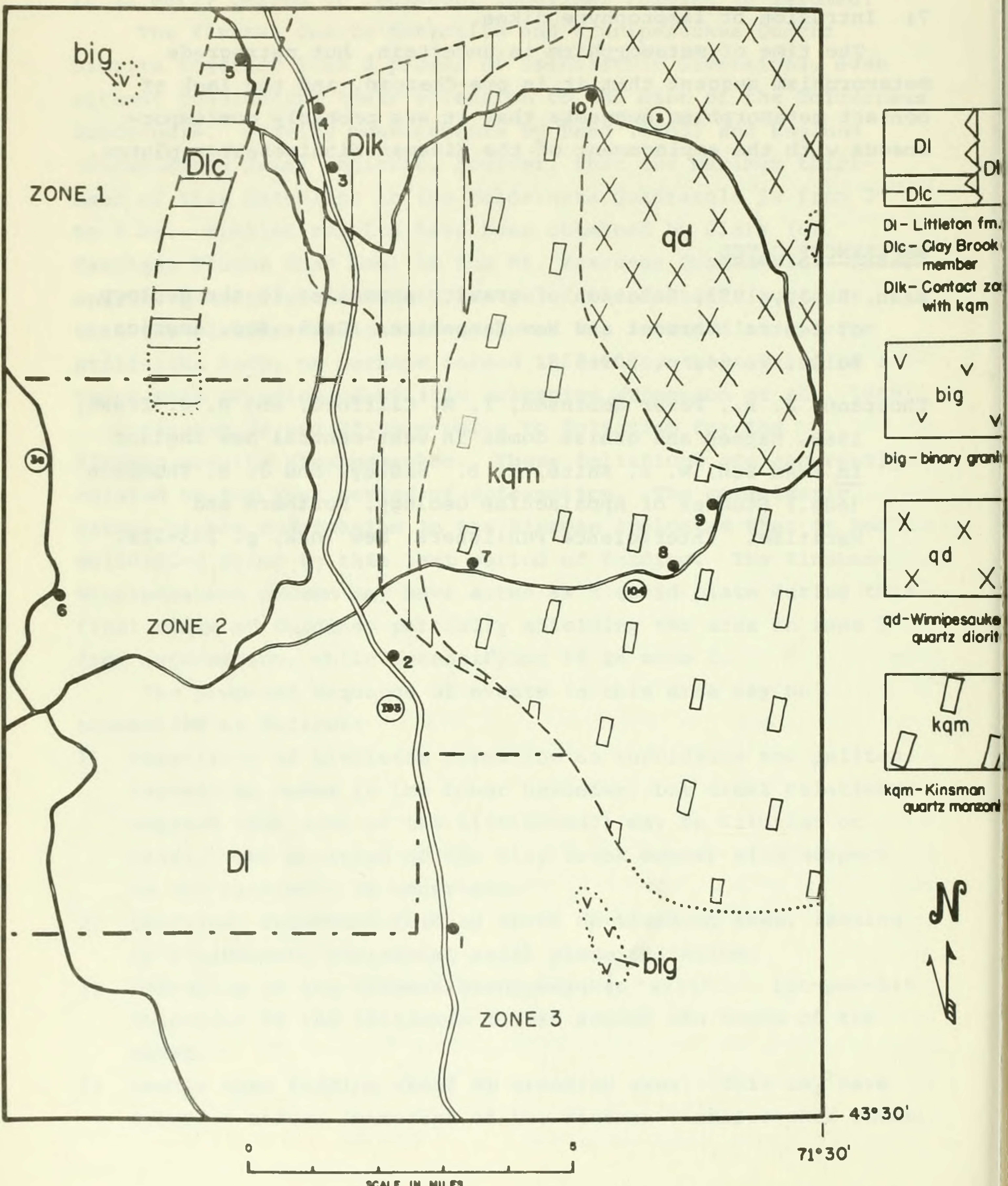
- 5) Folding about NE trending axes. More intense in zone 1 than in zone 3. Occurred after solidification of the Kinsman-Winnepesaukee pluton.
- 6) Intrusion of Concord granite.
- 7) Intrusion of lamprophyre dikes.

The time of metamorphism is uncertain, but retrograde metamorphism suggest that it is pre-Concord, and the lack of contact metamorphism suggests that it was probably contemporaneous with the emplacement of the Kinsman-Winnepesaukee pluton.

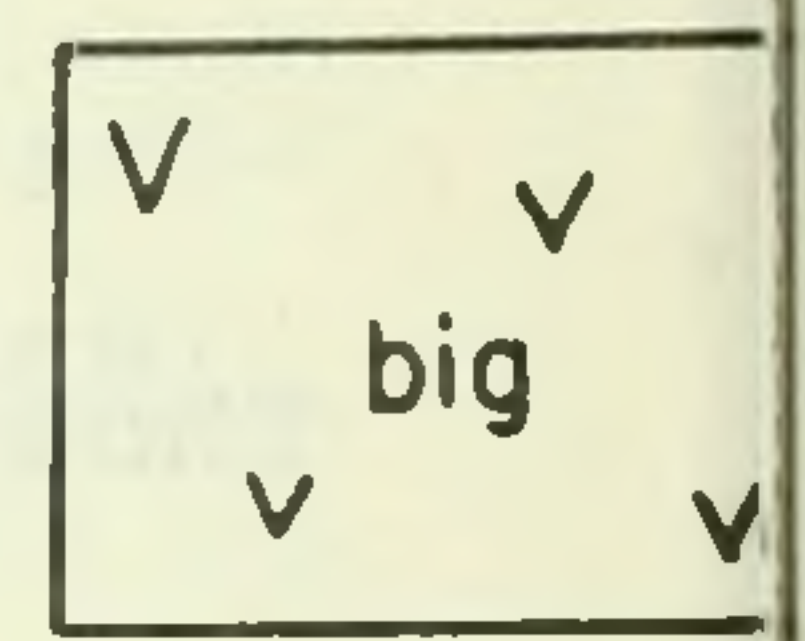
REFERENCES CITED

- Bean, R. J., 1953, Relation of gravity anomalies to the geology of central Vermont and New Hampshire. Geol. Soc. America Bull., v. 64, p. 509-538.
- Thompson, J. B., Peter Robinson, T. M. Clifford, and N. J. Trask, 1968, Nappes and gneiss domes in west-central New England in E-An Zen, W. S. White, J. B. Hadley, and J. B. Thompson (eds.) Studies of Appalachian Geology, Northern and Maritime. Interscience Publishers, New York, p. 203-218.

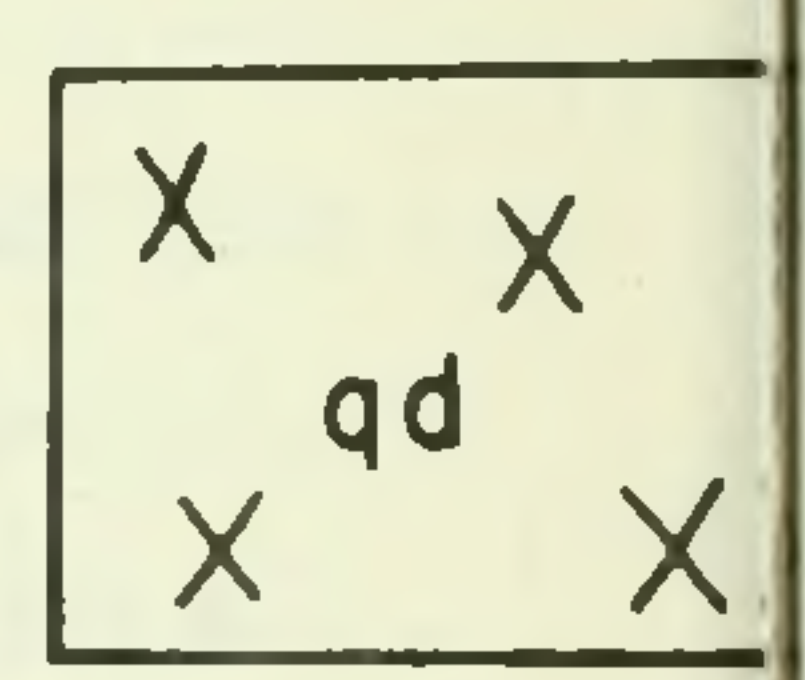
GEOLOGIC MAP of the HOLDERNESS QUADRANGLE, N.H.



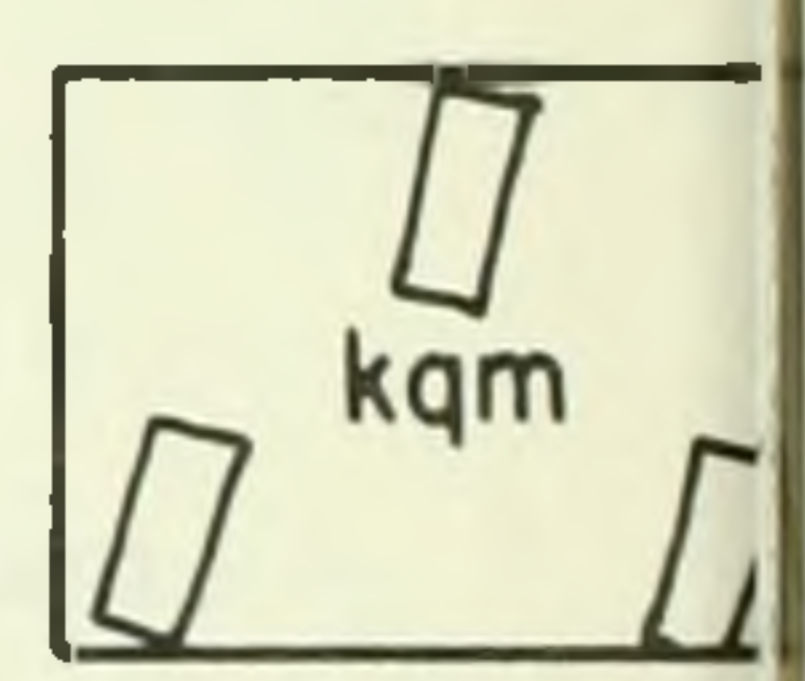
DI - Littleton fm.
Dlc - Clay Brook member
DIK - Contact zone with kqm



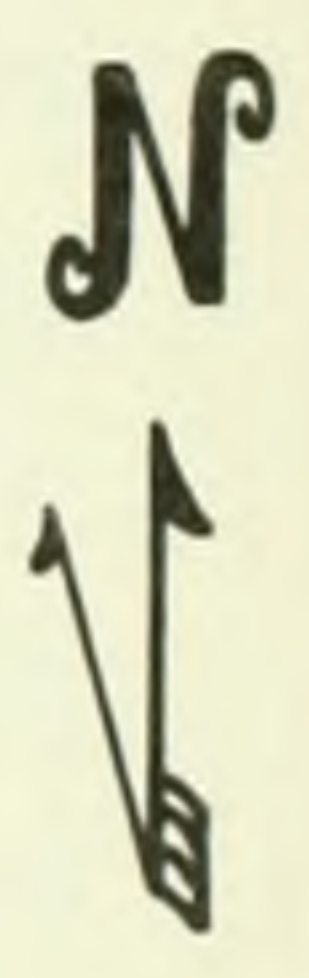
big - binary granite



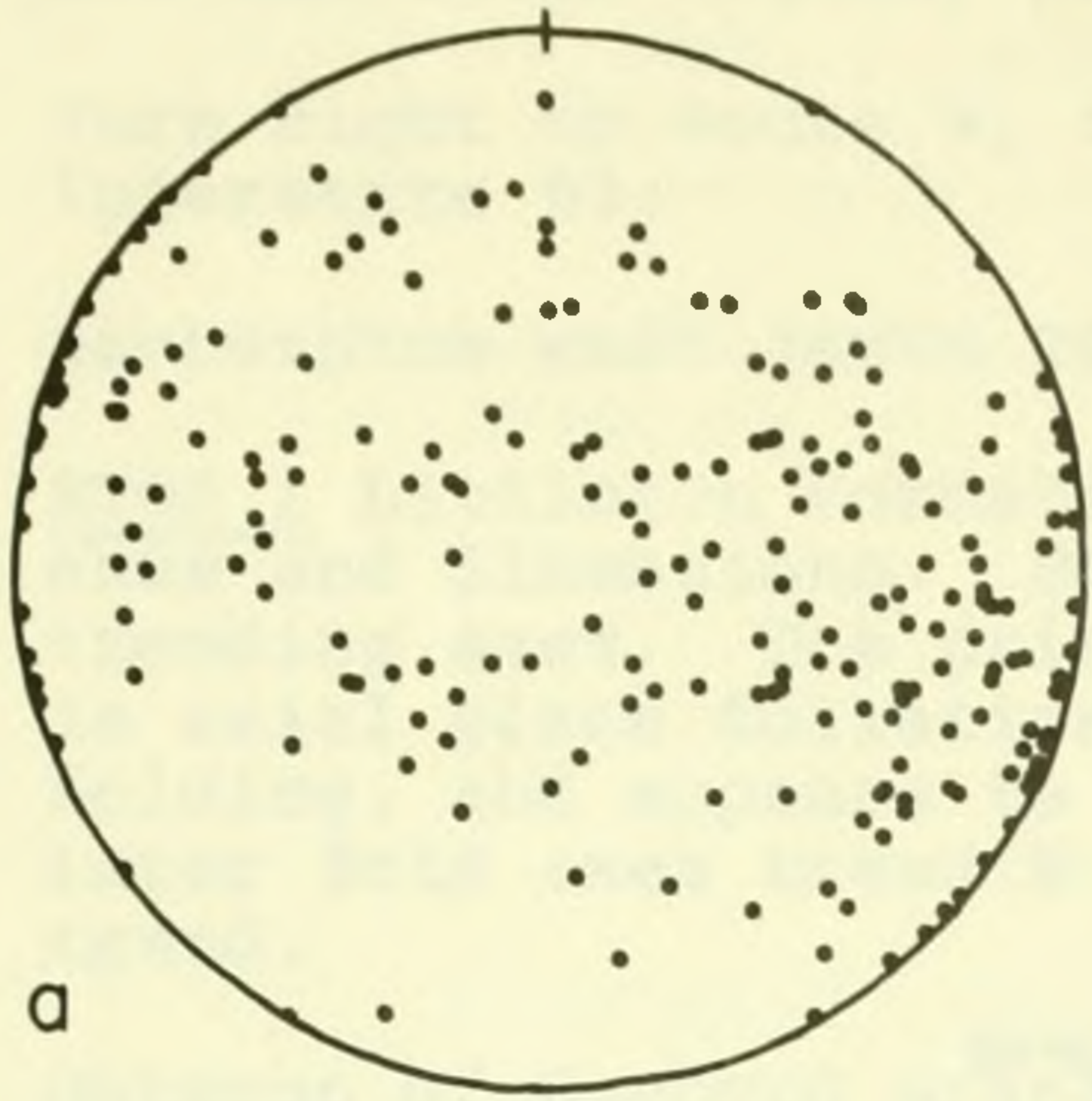
qd - Winnepesaukee quartz diorite



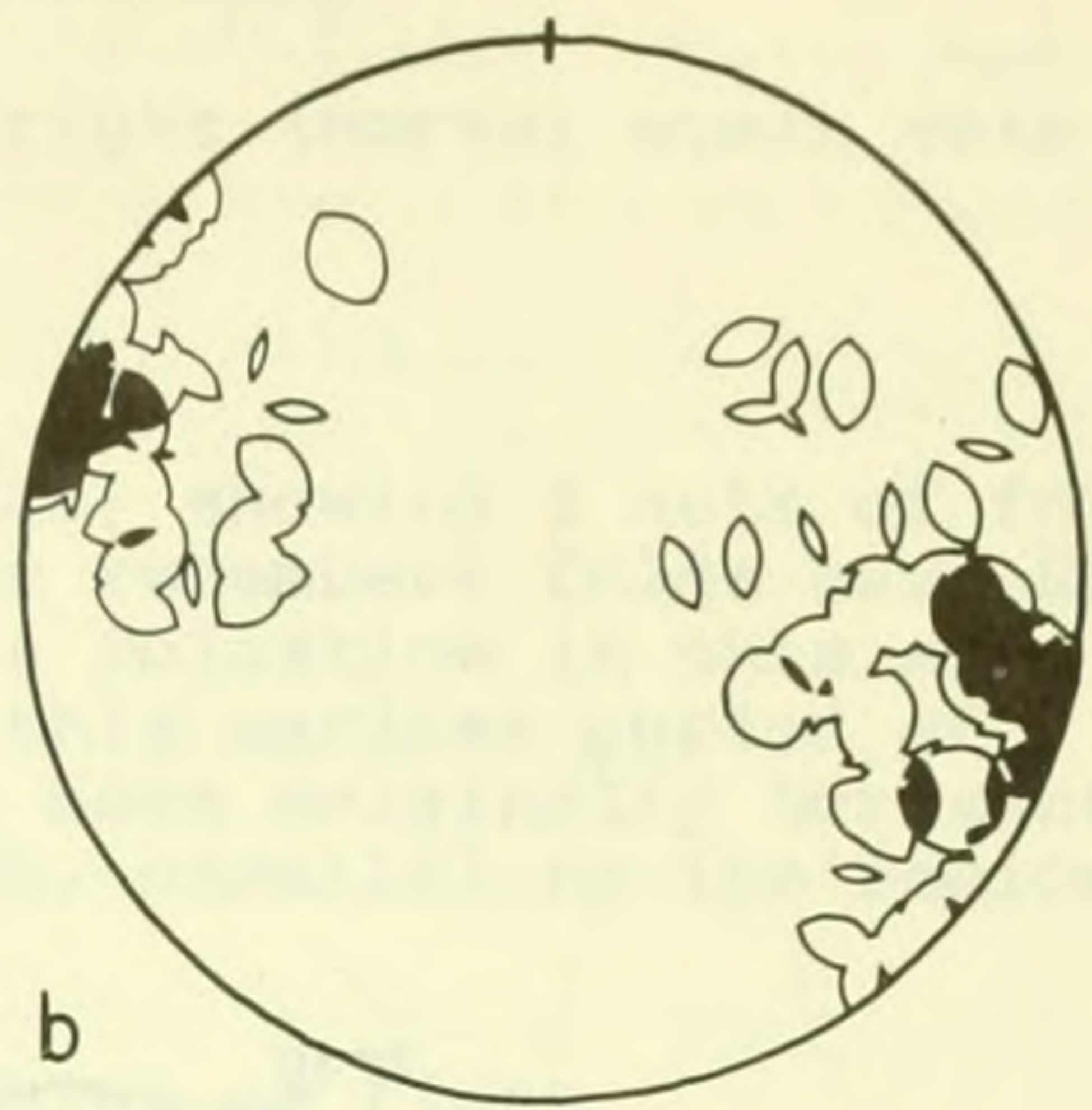
kqm - Kinsman quartz monzonite



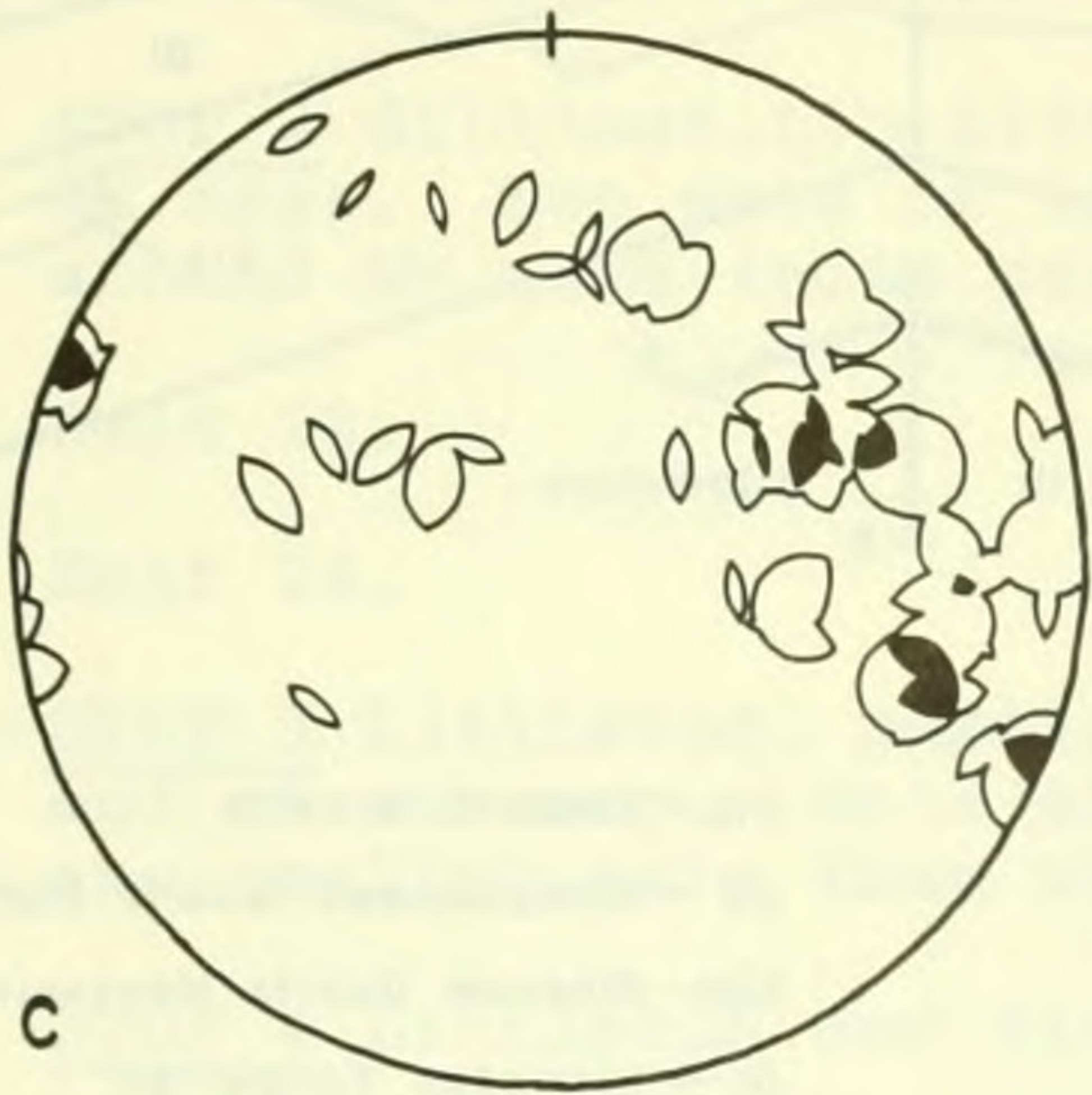
Equal Area Diagrams Showing Poles to Foliation



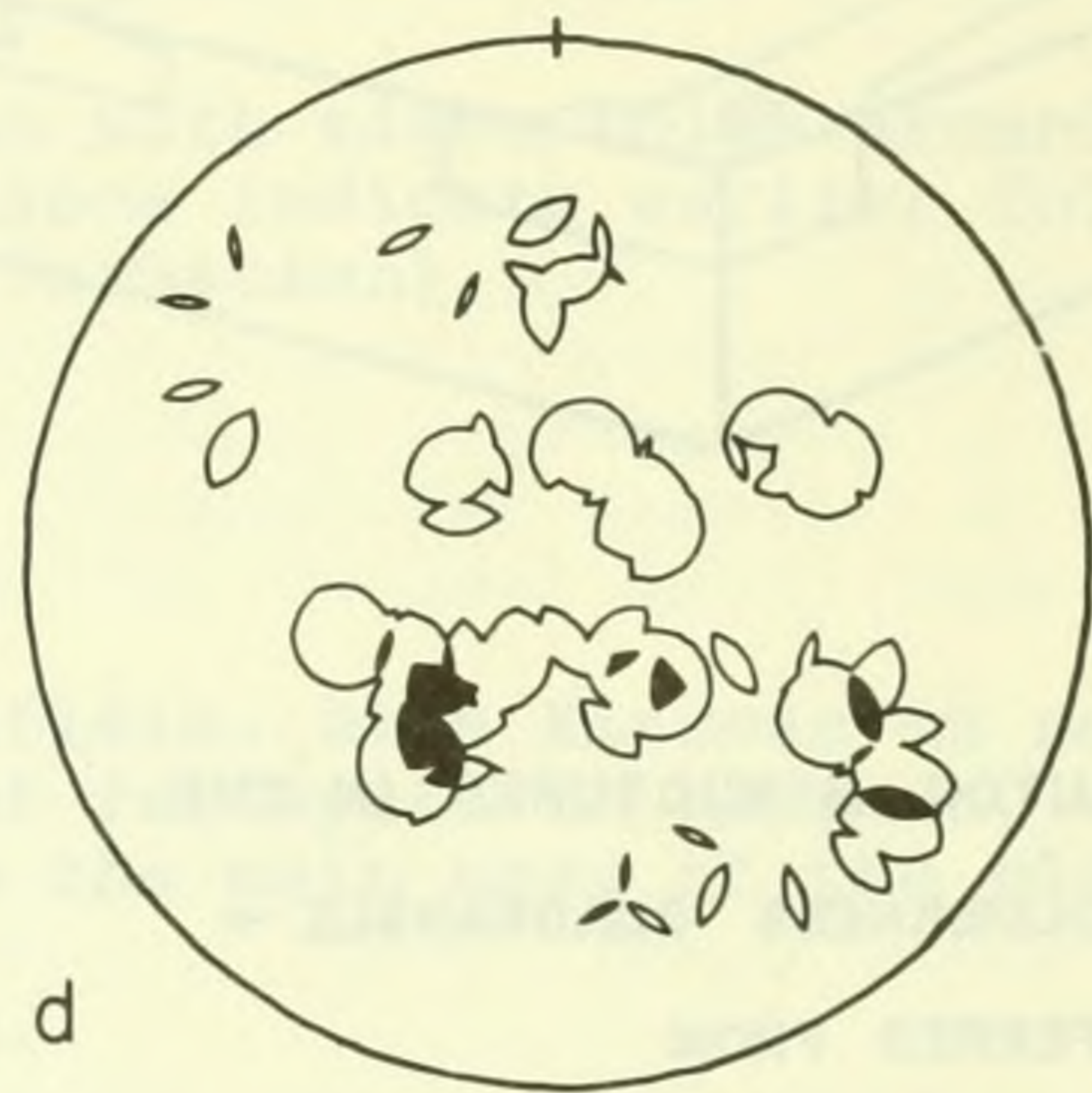
Total Littleton - 192 pts.



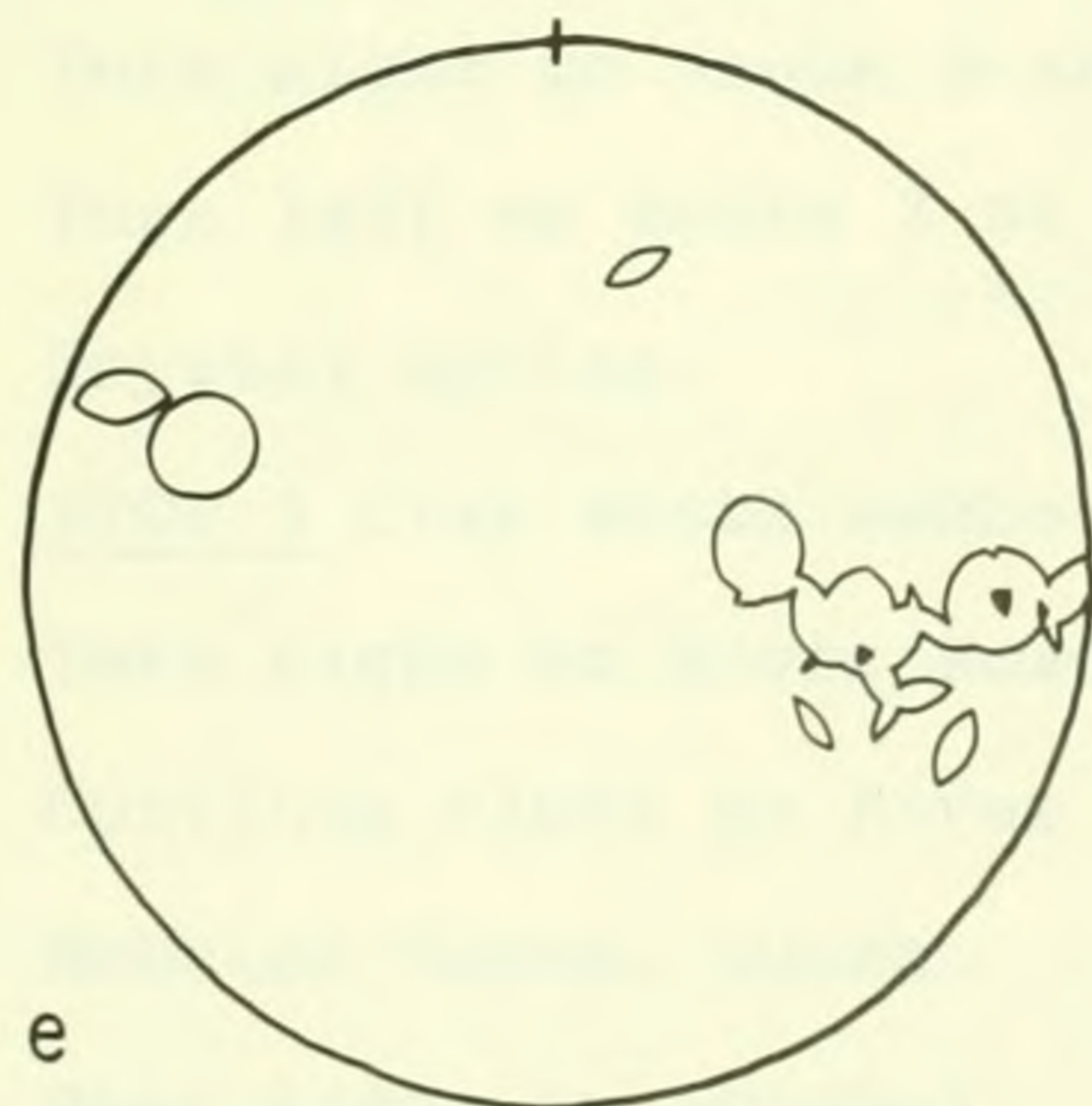
Littleton Zone 1 - 72 pts.



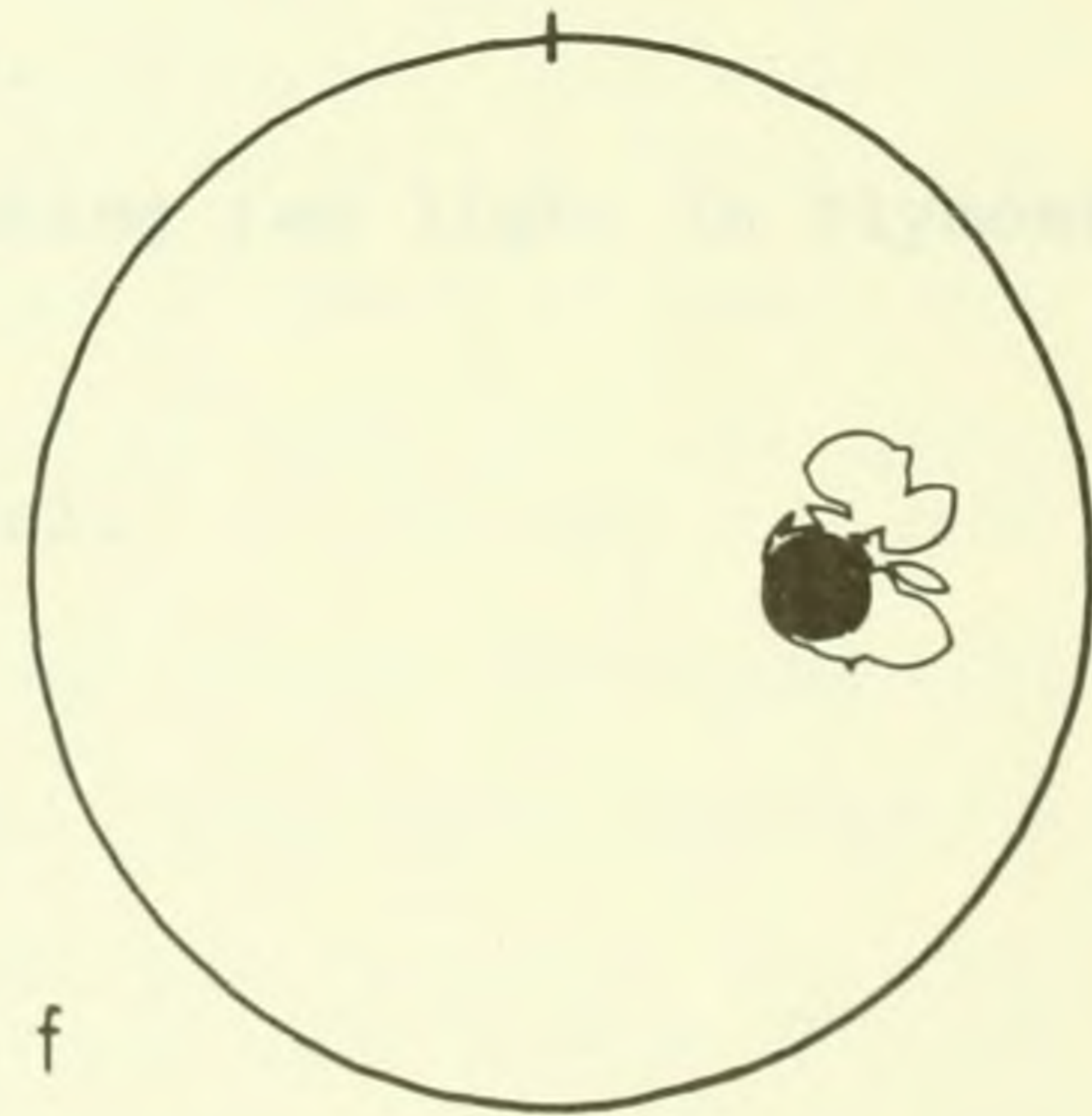
Littleton Zone 2 - 58 pts.



Littleton Zone 3 - 62 pts.



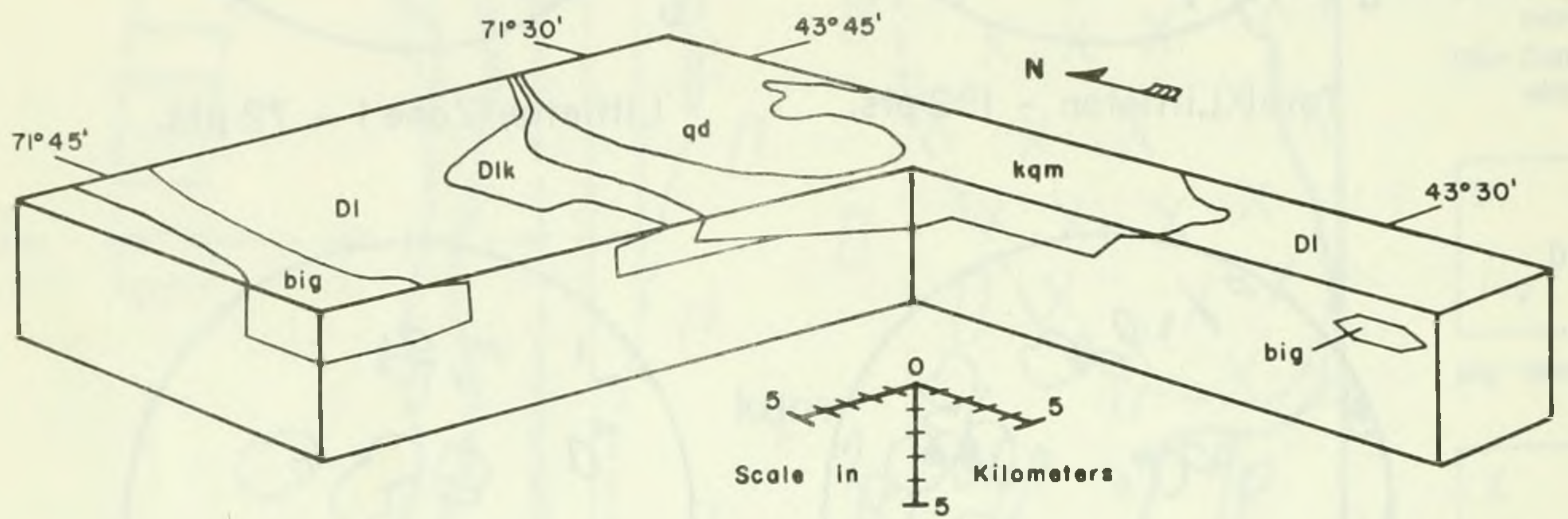
Kinsman - 29 pts.



Winnepesaukee - 17 pts.

Contour Maxima: b. 4%; c. 7%; d. 7%; e. 12%; f. 20%

Figure 2.



PLUTON STRUCTURES IN THE
 HOLDERNESS QUADRANGLE —
 INFERRED FROM
 GRAVITY ANOMALIES

big - Concord Granite
 qd - Winnepesaukee Quartz Diorite
 kqm - Kinman Quartz Monzonite
 DI - Littleton Formation
 Dlk - Kinman-Littleton Contact Zone

Figure 3.

ROAD LOG TRIP B-2

Mileage

- 0.0 New Hampshire Highway Hotel, Concord.
- 0.2 Turn right on Route 9, then right (north) again onto Interstate 93.
- 23.7 Sanbornton exit (exit 22).
- 26.6 STOP 1 Littleton Formation (D1) showing 2 sets of fold axes and lineations. Earlier recumbent folds have NW trending axes. The principle foliation in this area is axial plane foliation to this earlier period of folding, and appears to have been originally horizontal. Later fold axes trend N to NE, parallel to the regional trend.
- 28.3 Outcrop of Concord granite (big) on right.
- 29.1 Meredith Town Line.
- 30.4 New Hampton Town Line.
- 31.1 STOP 2 Sillimanitic Littleton with tight folds-around NE axes. Two sets of lineations indicate earlier folding around NW axes (note garnet formation).
- 31.7 Exit 23.
- 38.2 Exit 24.
- 39.3 STOP 3 Littleton, partly sulfidic, with Kinsman at northern end of outcrop. Note size of feldspars in Kinsman, which are smaller here than within the main mass of the pluton.
- 40.3 STOP 4 Littleton and Kinsman.
- 42.1 Holderness Town Line.
- 43.2 Turn right at exit 25.
- 43.4 Turn right to Route 3 and 25.
- 44.0 Turn left on Route 3 at blinking red light in Plymouth.
- 45.3 Crystal Spring.
- 45.6 STOP 5 Clay Brook member (D1c).
- 47.1 Turn right on River Road.
- 48.1 Continue right on River Road.
- 50.8 Webster farms. Lunch.
- 56.3 Bear right to Bristol.

- 57.0 Right on Route 104.
- 60.7 Bristol Square. Junction with Route 3A, turn right.
- 60.8 Bear right toward Newfound Lake.
- 63.3 Turn right at Cliff Lodges.
- 63.4 STOP 6 Banded Littleton. Synclinal fold, right-way up? Graded bedding, cross bedding, and boudins.
- Turn around
- 63.5 Turn left on Route 3A and return to Bristol.
- 66.0 Junction with Route 104 in Bristol.
- 66.1 Turn left on Route 104 at Bristol square.
- 70.7 Bridge across Pemigewasset River.
- 71.0 Littleton Formation with ptigmatic fold axes at right angles to main fold.
- 71.9 Interstate 93 Underpass, continue on Route 104.
- 73.8 STOP 7 Kinsman showing discordant structures (foliations), shear zones and xenoliths. Notable textural relations include biotite pseudomorphous after garnet and myrmekitic rims around K-feldspars. Note - compare size of megacrysts with those seen at STOPS 3 and 4.
- 77.1 STOP 8 Concord granite intruding Kinsman. Kinsman shows evidence of strong deformation. East end of outcrop contains a long xenolith(?) with development of K-feldspar megacrysts. Note K-feldspars replaced by quartz.
- 77.4 Outcrop similar to above. Note Lamprophyre dike. Fission track ages on 5 lamprophyres of the Holderness Quadrangle average 142 ± 8 m.y.
- 78.3 STOP 9 Kinsman with evidence of granulation and crushing. Compositional layering with K-feldspar-rich layers suggesting filter-pressing.
- 80.6 Turn left on Route 3 toward Meredith.
- 81.6 Meredith; junction with Route 25, continue north on Routes 3 and 25.
- 82.1 Winnipesaukee Quartz Diorite (Bethlehem Gneiss).
- 85.5 Holderness Town Line.
- 88.5 STOP 10 Contact zone between Winnipesaukee and Kinsman.
to This is one of the few places in New Hampshire where these
88.7 two units are in contact. Age relations are uncertain, but kqm may intrude wgd. Felsic and mafic dikes of White Mountain magma series cut the outcrop. Do the structures in

the Winnepesaukee suggest either a metasedimentary or a volcanic origin?

89.0 Outcrop of typical Kinsman on left.

91.1 Ashland town line.

93.6 Turn right on Route 3.

94.3 Junction with Interstate 93; proceed south on Interstate 93 to Concord.

END OF TRIP