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PRELIMINARY BEDROCK GEOLOGIC MAP OF THE PHILIP SMITH MOUNTAINS C-4 QUADRANGLE, NORTHEASTERN BROOKS RANGE, ALASKA

by

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BEDROCK UNITS

BROOKIAN SEQUENCE

The Brookian sequence was named by Lerand (1973) for a Jurassic (?) to Late Cretaceous age sedimentary secession in arctic Canada. In the Slope Mountain area, the Brookian sequence comprises approximately 4,000 m of marine and nonmarine deposits (Bird and Molenaar, 1987) shed northward from the Brooks Range uplift.

Nanushuk Group (Albian and Cenomanian)(Schrader, 1902; Gryc and others, 1951; Detterman and others, 1975) - Comprises an upper Chandler Formation and a lower Tuktu Formation. The environment of deposition interpretation for Slope Mountain (Marmot Syncline) rocks is based on our measured section on the east side of Slope Mountain. Here, a large-scale, shallowing upward succession consists of Torok Formation at the base overlain by Nanushuk Group Formations: Tuktu and Chandler. This succession represents a generally shallowing-up succession of prodelta shale (Torok), inner shelf, above storm wave-base sandstone (Tuktu), and delta plain, flood plain and braided stream, with overlying marine sandstone (Chandler).

Knc **Chandler Formation** (Albian to Cenomanian) - Gray, yellow-gray, and red-gray, fine- to course-grained lithic sandstone, interbedded with conglomerate, siltstone, coal, shale, and mudstone. Sandstone is thin to very thick bedded (up to 1 m thick), locally burrowed, in fining-upward successions, homogeneous to evenly plane-parallel bedded and evenly laminated, with locally abundant rippled top interval. Sandstone successions form resistant ledges up to 15 m thick separated by up to 70 m of generally poorly exposed black shale and mudstone. Sedimentary structures include ripples, small-to large-scale tough cross bedding, and tabular cross bedding. Sandstone commonly contains woody material up to 25 cm in diameter. Tan to red-gray, clast- to matrix-supported, subrounded chert and quartz pebble conglomerate is thin to very thick bedded, and commonly medium- to large-scale trough cross stratified. Near the basal Chandler Formation, conglomerate beds consists primarily of thin pebble lags. Conglomerate beds increase in thickness and abundance in the upper 75 percent of the Chandler Formation. Coal is poorly exposed and primarily consists of small chips of float. One Thermal Alteration Index value is 2.3 to 2.5. The basal Chandler is interpreted as lower delta plain, high bed load-stacked distributary channels, interbedded with bay, marsh and swamp deposits. The upper Chandler Formation contains braided stream and flood plain deposits. Near the top of Slope Mountain a transgressive sandstone marks a return to marine conditions. Better age control is needed to determine if this marine interval belongs in the Nanushuk Group or is in fact the base of the Colville Group at this locality.

Knt **Tuktu Formation** (Albian) - Gray, yellow-gray, and red-gray, very fine to fine-grained lithic sandstone, interbedded with siltstone, and shale mudstone. Sandstone is thin to very thickly bedded and commonly burrowed. Sedimentary structures include ripples, small-scale trough cross bedding, hummocky cross stratification, swaly cross stratification, planar bedding, sole marks and load casts. From our Slope Mountain measured section this unit is 180 m thick, and micropaleontology analysis yields Aptian to Albian and mid - late Albian ages; and Thermal Alteration Index values of 2.5 to 2.3 (Reifenstuhl and Plumb, 1993). Biogenic and sedimentary structures suggest shelf deposition above storm wave base. The Tuktu Formation overlies the Torok Formation; this contact may be a disconformity.

Kt **Torok Formation** - (Albian) (Gryc and others, 1951; 1956) Dark gray to black mudstone, silty mudstone, and shale, contains scattered nodules and concretions, becomes sandier upward and grades into lower beds of Tuktu Formation of the Nanushuk Group. In map area is well exposed only on lower part of Slope Mountain. More than 130 m thick; probably very thick and underlies lowland area south of Slope Mountain. Unit is relatively incompetent and probably acts as a detachment zone beneath the gently folded overlying Nanushuk Group. From the Slope Mountain measured section, micropaleontology analysis yields Aptian to Albian ages and Thermal Alteration Index values of 2.7 to 3.0 (Reifenstuhl and Plumb, 1993). The Torok Formation is interpreted as prodelta hemipelagic shale interbedded with low density turbidites, and lesser high density turbidites.

Kfm **Fortress Mountain Formation** (Albian) (Patton, 1956) - Dark-gray and greenish dark-gray, fine to coarse-grained graywacke sandstone, pebbly-sandstone, conglomerate, siltstone and interbedded

mudstone. Conglomerate clasts include dark-gray, black, green, greenish gray, and minor maroon chert, and lesser fine-grained mafic igneous rocks, leached silicified limestone, quartzite, plagioclase and other sedimentary rocks. On north side of Atigun Gorge consists of more than 15 thick massive intervals of graywacke and pebble- to cobble conglomerate up to 15 m thick that form cliffs, high ridges and cuestas on south flank of Atigun syncline. Unit thins and fines northward; on north flank of Atigun syncline unit consists of only 6 resistant ridge-forming graywacke and pebble conglomerate intervals separated by poorly exposed mudstone intervals. To north, consists dominantly of local conglomeratic graywacke that forms scattered high hills. Thickness over 3000 m in Atigun syncline. Top is a Holocene erosion surface, basal part of unit consists dominantly of graywacke sandstone, and is apparently gradational downward into underlying fine grained beds of our lower Fortress Mountain Formation. Contains pelecypods of Albian age in Atigun syncline (Brosge' and others, 1979).

Kfml **Lower Fortress Mountain Formation** (Albian). Gray to greenish-gray, hard silty mudstone and siltstone and thin graywacke sandstone beds containing conspicuous granules of light gray leached limestone and flakes of black oil shale (Tasmanite), with conspicuous zones of yellowish gray-weathering concretions concentrated along scattered bedding horizons. Over 500 m thick on north side of Atigun Gorge. Hard mudstone forms steep slopes beneath gradationally overlying cliff-forming graywacke and conglomerate of upper part of Fortress Mountain Formation; elsewhere to north is more poorly exposed. Contains Albian or older Lower Cretaceous pelecypods at east end of Atigun Gorge (W. P. Elder, written commun., 1990). Micropaleontology analysis yields Thermal Alteration Index values of 3.0 (Reifenstuhl and Plumb, 1993).

Kcs **Cobblestone sandstone unit** (Aptian? or upper Neocomian) (Kelley, 1990) - Sandstone, graywacke, dark-gray; weathers light- to medium-gray, fine- to medium-grained; some places very coarse to granular or conglomeratic, beds 1 to 3 m-thick form 20 to 30 m-thick sandstone interval with few shale breaks. Sandstone generally homogeneous but with some grading, scattered small-scale cross bedding, apparent megaflutes, and carbonaceous material; appears to be amalgamated turbidites, some places with interbedded 20 to 25 m mudstone interval separating dominantly sandy intervals. Sandstone consists dominantly of black, gray, greenish-gray, and light-green chert, rare dark-green and brown chert, some quartz, and up to 20 percent white to light-gray leached chert which gives the light-gray weathering character to outcrops. Interval has sharp base with floating granules to rounded pebbles of chert in basal 3 to 4 cm; basal contact is smooth undulatory surface overlying shale and mudstone. Top of unit, not well exposed, appears to grade upward over a short interval into a thick section of dominantly black shale of the Torok Formation or lower Fortress Mountain Formation. Forms isolated resistant ridges and ledges. Thickness approximately 30 to 70 m. Aptian (?) or late Neocomian age is inferred, based upon stratigraphic position bracketed regionally between Valanginian age coquinoid limestone unit and Albian age Fortress Mountain Formation.

Kp **Phosphatic shale unit** (upper Neocomian ?) - Unnamed hard mudstone and shale; contains finely disseminated phosphate, weathers reddish-brown to reddish-black, locally contains softer black clay-shale at top and base. Mapped locally in lowlands in western part of map area and at northeastern edge of map area. Considered part of the Kongakut Formation by Brosge' and others, (1979). Stratigraphic relationships obscure in map area, but to west in Chandler Lake C-1 quadrangle, the phosphatic shale underlies the Cobblestone sandstone unit of Kelley, (1990), and in Philip Smith C-5 quadrangle, the phosphatic shale and the Cobblestone sandstone are regionally overlain by conglomerate of Fortress Mountain Formation (C.G. Mull, unpublished mapping). At the eastern edge of the Philip Smith Mountains C-4 quadrangle, the unit is less resistant than to the west, but has intervals with conspicuous reddish-brown weathering character, which contrast with the dominantly black-weathering of shales of the Torok Formation, which it otherwise generally resembles. Where well exposed in the Chandler Lake C-1 quadrangle, the phosphatic shale unit is about 30 m thick; it is generally poorly exposed in the Philip Smith Mountains C-4 quadrangle but may be thicker than to the west. Chemical analysis of one sample from the Chandler Lake C-1 quadrangle yields: 0.7 percent Mg, greater than 10 percent Fe, 6979 ppm Mn, 158 ppm Zn, 1743 ppm Sr, and 128 ppm As. Comparison with geochemical analyses of shales worldwide (Turekian and Wedepohl, 1961) shows that arsenic is 13 times, manganese is 8.2 times, and strontium is 4.4 times greater than worldwide averages.

Ko **Okpikruak Formation** (Lower Cretaceous) (Gryc and others, 1951) - Graywacke, dark-gray to black, fine- to medium-grained, finely to abundantly micaceous in places, thinly interbedded with black clay-shale, contains conspicuous flute and groove casts and other sole markings indicative of turbidite deposition. Exposed as intensely deformed broken formation in Atigun Gorge, 5 km south of map area. In map area is apparently tightly folded in high rubble-covered hills with scattered exposures. In map area nature of contacts with adjacent units is unknown owing to poor exposures, but in Atigun Gorge, formation base is a major fault that is probably an allochthon boundary with large scale displacement (Mull and Glenn, 1991; Mull, unpub. mapping). Upper contact of Okpikruak with overlying lower part of the Fortress Mountain Formation in Atigun Gorge is a fault, but regionally is probably an unconformity. Contains pelecypods of Valanginian age (lower Neocomian) in Atigun Gorge south of map area (W.P. Elder, written commun., 1990). Palynology analysis of Atigun Gorge samples yields ages of: Hauterivian to Barremian and Thermal Alteration Index values of 3.0 (Reifenstuhl and Plumb, 1993).

ELLESMERIAN SEQUENCE

The Ellesmerian sequence was named by Lerand (1973) for a Mississippian to Jurassic age sedimentary succession in arctic Canada. Ellesmerian sequence rocks which cropout in the Philip Smith Mountains C-4 quadrangle, include: Alapah Limestone and Wahoo Limestone of the Lisburne Group (Mississippian and Pennsylvanian, respectively), Sadlerochit Group (Permian and Triassic), and Etivluk Group rocks (Permian to Jurassic): Siksikpuk Formation (Permian), Imnaitchiak Chert(?) (Triassic to Permian), and Otuk Formation (Middle Jurassic to Middle Triassic).

ETIVLUK GROUP (Pennsylvanian to Middle Jurassic) (Mull and others, 1982, 1987)--Includes Siksikpuk Formation (Patton, 1957) and Otuk Formation (Mull and others, 1982) of the Endicott Mountains allochthon, and Imnaitchiak Chert (Mull and others, 1987) of the Ipnavik River or Picnic Creek allochthon.

JTro **Otuk Formation** (Middle Jurassic to Middle Triassic) - Thinly interbedded black shale and light-gray weathering black limestone with abundant *Monotis* and *Halobia* pelecypods, and thin beds of banded black chert with wispy lamination. In map area present only as small rubble outcrop in gully (SW1/4, Sec. 21, T. 9 S., R.13 E.: Brosge' and others, 1979), but is also present extensively in Atigun Gorge 5- to km south of map area and locally east of map area. One km south, in the Philip Smith Mountains B-4 quadrangle, conodonts from the upper part of the Limestone Member yield a late Middle to Late Triassic age and a CAI value of 2 (Anita Harris, written commun., 1993).

TrPc Chert, (Triassic to Permian) - White and black banded, some greenish-gray, thin-bedded, forms 75 m diameter rubble-covered hillside in NW 1/4 of Sec. 20, T. 10 S, R.14 E., relationship with Okpikruak Formation to north is unknown owing to poor exposures. Lithologically resembles Imnaitchiak Chert of western Endicott Mountains. Similar isolated exposures of chert in Atigun Gorge mark tectonic boundary between Otuk Formation on Endicott Mountains allochthon and overlying Okpikruak Formation (Mull and Glenn, 1991). Probably represents fault sliver remnant of Picnic Creek or Ipnavik River allochthon emplaced along a major structural zone above the Endicott Mountains allochthon before deposition of Fortress Mountain Formation; this structural zone, marked by slivers of chert, trends eastward into the adjacent quadrangle.

Ps **Siksikpuk Formation** (Permian)(Patton, 1957; Adams and Siok, 1989) - In central and western Endicott Mountains, the formation consists of four units: unit A is 5 m-thick yellowish-brown-weathering dark-gray calcareous and slightly glauconitic, fossiliferous siltstone characterized by the trace fossil *Zoophycos*; unit B is red and greenish-gray to gray-mottled siltstone and mudstone with barite and siderite nodules; unit C is gray-green siliceous mudstone with interbedded shale; and unit D is recessive-weathering, dark-gray to black fissile shale. Eastward into the Philip Smith Mountains, units B and C are less prominent, the formation consists dominantly of units A and D, and is transitional into the Sadlerochit Group of the northeastern Brooks Range. The Siksikpuk-Echooka Formation transition takes place in the Accomplishment Creek and Saviukviayak River area, Philip Smith Mountains C-3 and D-2 quadrangles. Locally a well developed, steeply south-dipping cleavage is the dominant rock fabric; the Siksikpuk Formation may be a detachment horizon west of the Ribdon River and in the Accomplishment Creek area. In the Philip Smith Mountains C-4 map area, is exposed only in Atigun Gorge, and south of

the quadrangle boundary, where only units A and D cropout. Age of the Siksikpuk Formation is Lower Permian (Wolfcampian) to Upper Permian (Guadalupian, Brosge and others, 1979; Adams, 1991; Anita Harris, written commun., 1993).

TrPs **Sadlerochit Group undifferentiated** (Permian to Lower Triassic)(Leffingwell, 1919; Keller and others, 1964) - Siltstone, dark-gray, mottled, apparently bioturbated, locally with *Zoophycos* and other trace fossils; and, hard, dense, quartzite with scattered limonitic spots, and thin barite seams. Interbedded with black silty shale. Exposed only at eastern edge of map area; resistant units 2 to 3 m thick form mostly rubble-covered hills and local ridges; total interval may be >100 m thick unless structurally imbricated. Overlies about 100 m of mostly covered interval underlain by black silty mudstone that appears to overlie Lisburne Group with no exposures of Echooka Formation or unit A of Siksikpuk Formation. Overlying beds unknown owing to poor exposures. Section does not resemble Siksikpuk Formation in adjacent areas, stratigraphic sequence is more similar to a distal equivalent of the Kavik Shale and Ivishak Formation of Philip Smith Mountains 30 km northeast of map area. With Lisburne Group, this section forms folded and faulted thrust sheet that locally is both structurally above and below thrust sheets with Siksikpuk Formation and Lisburne Group rocks.

LISBURNE GROUP (Mississippian to Lower Pennsylvanian)(Schrader, 1902) Named for a thick succession of light gray limestone in the Cape Lisburne area of the western Brooks Range. Leffingwell (1919) later referred to similar rocks in northeastern Alaska as the Lisburne Limestone. Detailed work by Bowsher and Dutro (1957) in the Shainin Lake area of the central Brooks Range subsequently raised the Lisburne Formation to group status and subdivided it into two formations: Alapah Limestone (Upper Mississippian), and Wachsmuth Limestone (Lower and Upper Mississippian) which apparently thins to the northeast. In the northeastern Brooks Range, the Alapah Limestone is overlain by the Wahoo Limestone (Brosge' and others, 1962) of Late Mississippian to Early Pennsylvanian age (Imm, 1988; Armstrong and others, 1970). In the Philip Smith Mountains C-3 quadrangle, on Accomplishment Creek, the top of the Lisburne Group is Early Pennsylvanian (middle Morrowan-late Wolfcampian; CAI 4, Anita Harris, written commun., 1993).

PMl **Lisburne Group undivided** - (Mississippian to Lower Pennsylvanian) The Lisburne Group description above, and field mapping recognize Wahoo Limestone and Alapah Limestone units where possible but on this preliminary map are included in the 'Lisburne Group undivided' unit. Also included in our 'undivided unit' is the Wachsmuth Limestone locally mapped in the western Philip Smith Mountains quadrangle by Brosge' and others (1979). To the east of our map area, in the adjacent Philip Smith Mountains C-3 quadrangle, the Wahoo Limestone consists of light-gray to buff and tan, and light-yellow, fine- to medium-grained, thin- to massive-bedded, interbedded lime mud and bioclastic grainstone. Bedding ranges from a few centimeters to 15 m thick near the base. Irregular layers and nodules of gray and black secondary chert are common. The Wahoo Limestone contains abundant crinoids, brachiopods and bryozoan fauna, and locally, tan, thin-laminated dolomitic beds. Thickness is approximately 400 m (A.P. Krumhardt, unpub. data). The upper part of the Alapah Limestone is light- to medium-gray, thin- to medium-bedded limestone and lime mudstone which weathers into small, buff-colored, shard-like irregular pieces. Locally, thick-bedded to massive, and chert horizons and nodules may be common. Upper Alapah forms distinctive talus aprons below the Wahoo Limestone. The upper Alapah Limestone comprises the top of the Lisburne section west of the Ribdon River, where it forms steep, rugged outcrops. The upper Alapah is distinctly lighter gray than the lower Alapah. The lower part of the Alapah Limestone is very-dark-gray to light-gray, and tan, thin- to massive-bedded limestone consisting predominantly of pelletoidal packstone and grainstone in a distinctive cliff-forming unit below the upper Alapah Limestone. The contact between the upper Alapah and the lower Alapah appears to be gradational. Total thickness of the Alapah Limestone is approximately 100 m (A.P. Krumhardt, unpub. data). East of the Ribdon River, the Wahoo is deformed by east-plunging, tight, symmetric detachment folds, with subvertical axial planes, and several hundred to several thousand-meter wavelengths. The lower Alapah is thrust over the upper Alapah locally west of Accomplishment Creek. The upper Alapah forms the high peaks, and the dominant structural trends are southwest-plunging detachment folds (F_1), and local south-vergent folds. The latter structures may be the result of fault- and fold rotation and overturning by post-F_1 folding.

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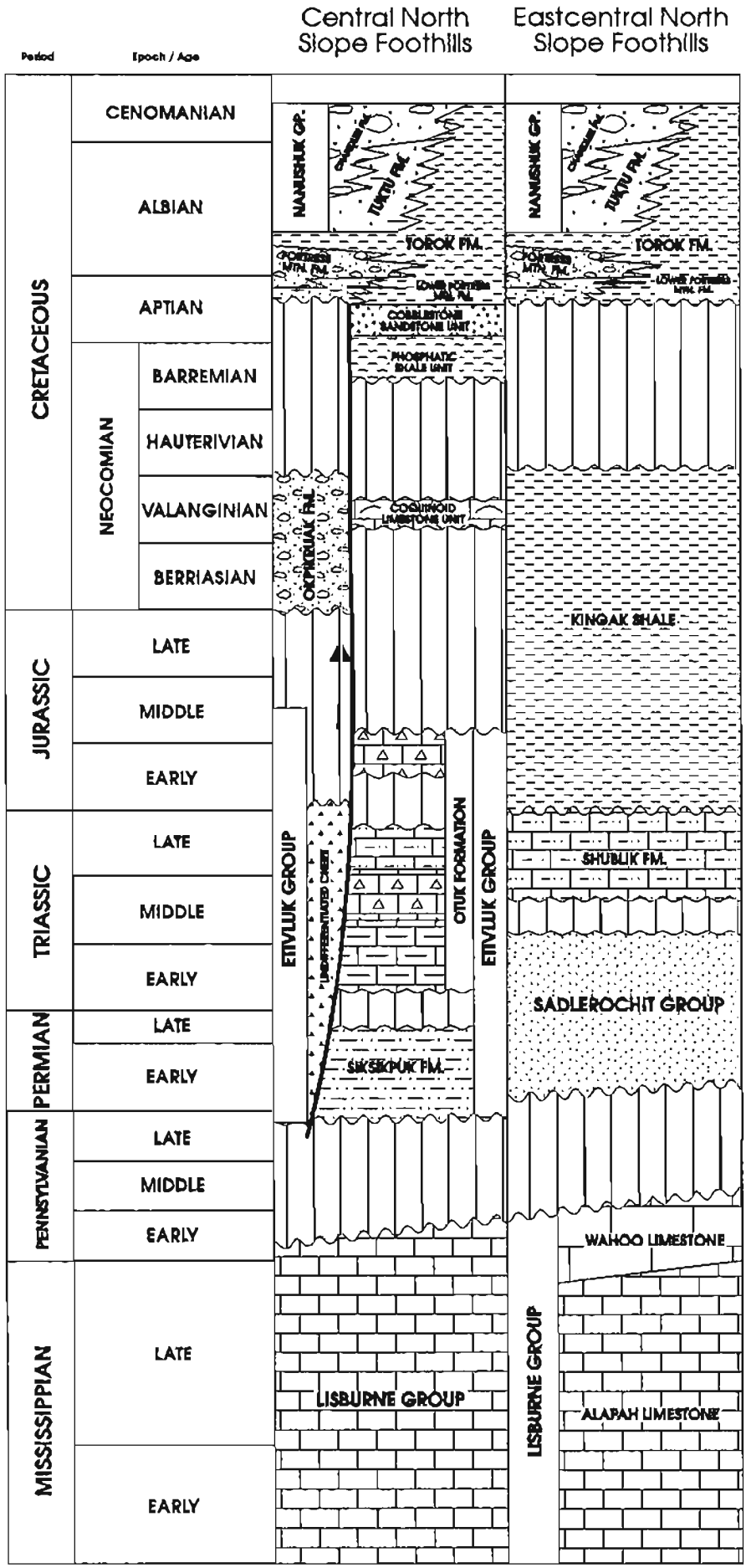
Stratigraphic Correlation of Map Units



MAP SYMBOLS

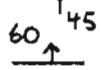
Contact - Solid where known; dashed where inferred; queried where uncertain.

High Angle Fault - Solid where known; Dashed where approximately located; dotted where concealed; queried where uncertain; D,downthrown side; U,upthrown side.

Thrust Fault - Sawteeth on upper plate; Dashed where approximately located; dotted where concealed; queried where uncertain.

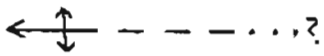
Strike and dip of beds
Inclined

Overturned

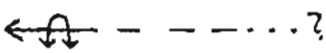


Estimated strike and dip from a distance

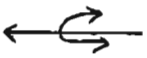
Folds - Showing trace of axial plane; shows direction of plunge where known; dashed where approximately located; dotted where concealed; queried where uncertain.



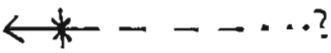
Anticline



Overturned anticline



Minor anticline



Syncline

Strike and dip of cleavage