INTRODUCTION

The Hamme district, North Carolina (fig. 1), is the only area in the Eastern United States with a history of tungsten mining. The district has been a major producer since World War II, and it contains the largest known classic example of wolframite-type quartz-vein deposits in the United States. In these deposits the wolframite-type mineral (here, huebnerite) is associated with fluorite and various sulfides in quartz veins cutting a plutonic granitic body. Tungsten was discovered in the Hamme district in 1942. Mining began in 1943 (Espenshade, 1947, p. 2–3) and was continued with slight interruption until 1963, when production was stopped because of declining tungsten prices. Mining was started again in 1970, but it was stopped in the fall of 1971 after a sharp drop in the price of tungsten. Total production has been about 1 million short ton units of WO_3.

In 1970, through the generosity of Ranchers Exploration and Development Corporation, deeper workings than those developed at the time of Espenshade's study, extending between 500 and 1500 ft (152 and 457 m) below the surface, were made available for study. Mineralogy and structures are remarkably uniform throughout these parts of the mine and conform closely with Espenshade's observations at shallower depths. A new level, 1700 ft (518 m) below the surface, was being opened in 1970, but it was not examined. The principal mine workings, except for the new level, and areas accessible in 1970 are shown in figure 2.

The most productive zone of the deposit consists of a mineralized vein which is slightly more than a mile (1.6 km) long and occurs in a narrow sericitized shear zone, mainly in the marginal part of a granodiorite-tonalite pluton. The principal mineralized vein and other tungsten-bearing veins to the northeast and southwest of the principal vein occupy a belt 8 mi (12.8 km) long (Espenshade, 1947, p. 2). Although most of the mineralization is within the pluton, the southwest part of the principal vein angles across the western edge of the pluton into phyllite of the bordering Carolina slate belt, and some tungsten production has come from parts of the vein within the phyllite (figs. 2, 3; Parker, 1963, p. 12, 62). The principal mineralized vein is cut by two north-northwest-trending diabase dikes of Triassic age (figs. 2, 6).

The pluton is one of a number of lower Paleozoic metagranitic intrusions emplaced into rocks of the Carolina slate belt (Sundelius, 1970) about the time a major deformation was ending (Glover and Sinha, 1973) and before or during the early stages of regional metamorphism (Butler and Ragland, 1969). The slate belt host rocks near the pluton are mainly of volcanic origin (Hadley, 1973) and evidently are latest Precambrian and Cambrian in age. According to Hills and Butler (1969), they are in the age range of 565±50 m. y. to 525±15 m. y. More recently Glover and his associates (Glover and others, 1971; Glover and Sinha, 1973) have found zircon ages as old as 620 m. y. in some of the slate belt rocks and ages of as much as 740 m. y. in gneiss that may be a high-grade metamorphic facies of slate belt rocks. Other slate belt rocks, however, are Cambrian in age based on the presence of trilobites (St. Jean, 1965; Stromquist and Sundelius, 1969).

The main episode of Paleozoic regional metamorphism in the Blue Ridge-Piedmont area of the Appalachians took place before 400 million years ago, but metamorphism may have been episodic, with culminations at different times in different parts of the area. The peak of metamorphism may have occurred less than 400 million years ago in the slate belt (Butler, 1972), but it can only be bracketed between 300 and 520 m. y.

Plutonic rocks of the Piedmont fall into three age groups: 1) 595–520 m. y., 2) 415–385 m. y., and 3) 300 m. y. (Fullagar, 1971, p. 2852). The oldest group of plutons occurs only in or adjacent to Carolina slate belt rocks and may be intrusive equivalents of the volcanic rocks of the slate belt (Fullagar, 1971, p. 2854; Butler and Ragland, 1969, p. 180). The pluton in which the Hamme deposit occurs is foliated and has been metamorphosed, as shown particularly by the alteration of original mafic minerals. Foliation of the plutonic rocks appears to be generally conformable with that of the slate belt rocks. Because of its metamorphism and location in slate belt rocks, the pluton of the Hamme deposit probably belongs to Fullagar's 595–520 m. y. group.

The slate belt rocks have a strong regional foliation (Hadley, 1973) trending north to north-northeast along the west side of the pluton near the Hamme mine (Parker, 1963, pl. 1). This foliation probably formed shortly after folding that produced the Virgilina synclinorium 15 mi (24 km) to the west, 625±20 m. y. to 575±20 m. y. ago (Tobisch and Glover, 1971, p. 2212; Glover and Sinha, 1973). It seems likely that the deformation producing the Virgilina synclinorium preceded the beginning of Paleozoic regional metamorphism, and it may have preceded the major middle Paleozoic metamorphism by 150 to 220 m. y.

The pluton is elongate in a north-northeast direction, almost parallel to the trend of the Virgilina synclinorium. The sericitized shear zone that contains the principal mineralized vein has a more northeasterly trend (fig. 3). Most nearby veins parallel the principal vein and a few diverge west to northwest. The age of mineralization is not known, but if mineralization is related to crystallization of the granite after emplacement of the pluton and regional deformation, as the quartz vein-wolframite-plutonic granite association suggests, then mineralization would have occurred at a late stage, after most of the pluton had solidified and the shear zone had formed and been sericitized. As solidification of the pluton was completed, the ready availability of late-stage solutions would have facilitated both sericitization and the deposition of vein quartz in the shear zone.

The principal vein, which trends northeastward and dips 60° to 80° SE (fig. 4A), is cut by two pronounced sets of joints, a west-northwest steeply dipping set and a flat-lying set (fig. 4B). Many other joints vary in attitude somewhat from the major sets. The most conspicuous joints are steeply dipping and approximately perpendicular to the trend of the principal vein. The flat joints are approximately perpendicular both to the major steeply dipping joints and to the dip of veins. Huebnerite crystals commonly are broken by large joints crossing the vein, especially joints of the steeply dipping set, and the fractures are healed by recrystallized quartz. The joints, therefore, are considered to be younger than mineralization.

Tungsten in the Hamme district occurs mainly in the form of huebnerite, the manganese end member of the wolframite series, and in much lesser amounts in the form of scheelite. Huebnerite is both scattered irregularly within veins of white quartz and confined along seams within the veins.

Accessory fluorite and sulfide minerals are common in the deposit (Espenshade, 1947, p. 6–9). Pyrite, by far, is the most abundant sulfide in wallrocks near the vein as well as within the vein. Chalcopyrite, galena, and sphalerite are also common in the the vein, and tetrahedrite is seen in a number of places. Molybdenite and rhodochrosite are comparatively rare. An unidentified mineral, common in films and tiny flakes in the quartz veins, fluoresces bright orange red and may be pyromorphite of supergene origin (Espenshade, 1947, p. 8).

The paragenetic sequence was listed by Espenshade (1947, p. 9) as quartz, sericite(?), pyrite, heubnerite, rhodochrosite, fluorite, scheelite, tetrahedrite, galena, chalcopyrite, and sphalerite. Sphalerite, however, at least at depths of 500 ft (152 m) and greater, is older than tetrahedrite, galena, and chalcopyrite, which commonly vein and partially rim the sphalerite. Also, along the shear zone in which the quartz veins are localized, sericitization of the granitic rock probably preceded emplacement of the veins.

The Hamme deposit consists largely of overlapping en echelon mineralized quartz pods which are separated by thin septa of schist produced by the sericitization of sheared granitic rock. Proceeding from northeast to southwest, the en echelon pods are offset westward (fig. 5A). Warps and minor folds in schist inclusions within pods commonly plunge steeply south-southwest to south-southeast (fig. 4C), and adjoining folds are staggered en echelon to the southwest consistent with offsets of the vein-quartz pods. Thus, the pods in effect form a system of overlapping, steeply plunging ribbons.

The minor folds and vein-quartz pods evidently are related. The emplacement of the vein-quartz pods appears to have been controlled by plunging folds and warps in schist along the shear zone. Veins replace warped schist, and pinch and swell, mimicking some broad open folds in the foliation (figs. 5A, D, E, F). Lodes plunge approximately parallel to the fold axes, with plunges noticeably steeper in the southern part of the mine than in the northern part (fig. 6). North of No. 6 shaft, plunges are 42°–48° SW, whereas south of there, plunges are 58°–65°. Down plunge, ends of lodes define lines that plunge about 30° NE. These lines separate three northeast-dipping zones within the mine, along which mineralization is absent. The reason for the interruption of mineralization along the northeast-dipping zones is not known.

The lodes in the three zones are numbered here for convenience—lodes 1–3 in the lowermost zone, lodes 4–7 in the middle zone, and lode 8 in the upper zone. Lodes 1–3 appear to continue downward below the deepest workings, and lodes 4, 5, and 8 are truncated by the land surface. Lodes 6 and 7 appear to be essentially complete within the confines of the mine. The near alinement of lode 3 in the lower zone and lode 4 in the middle zone, as well as the apparent downward continuation of the lowermost zone to the northeast, suggest that additional lodes may be present beneath lodes 5–7, perhaps alined directly with or slightly offset from the direction of their elongation.

The similar forms of some vein-quartz pods and warps in the schist enclosed in the pods, and similar plunges of drag folds, warped surfaces of quartz pods, and mineral lodes indicate that plunging folds and warps along the shear zone provided channelways along which silicon-rich mineralizing solutions moved up. The mineralization developing along such channelways evidently was interrupted along northeast-dipping zones and limited the plunge length of lodes to about 1,400 to 2,000 ft (427–610 m).

Quartz pods of the main productive vein contain two principal internal structural features, one a conspicuous sheeting that trends north-northeast more or less parallel to the walls (fig. 4D), the other a faint north-trending foliation which commonly diverges from sheeting surfaces (figs. 5, 7). The latter feature is marked principally by paper-thin sericite seams, commonly mineralized, and also by some thicker schist septa within the veins. The schist inclusions generally tail out into the quartz. Time and genetic relationships between the north-northeast trending and north-trending structures are uncertain. The principal quartz pods and sheeting obviously conform to a fracture-shear zone in the granitic rock that extends southwestward into slate belt rock. Granitic rock along the zone has been crushed and sericitized. The vein quartz pods along that part of the zone are encased in a thin sheath of sericite schist (altered granitic rock). Foliation in the wallrocks and in schist inclusions in the veins conforms closely to vein walls and sheeting (fig. 4A, D, E).

The origin of the divergent seams that trend northward across the quartz veins is obscure and theoretically might have any one of a number of explanations. Two possible explanations seem most plausible: 1), that the divergent seams represent a relict regional foliation preserved in the northeast-trending shear zone; 2), that a reorientation of northeast-trending foliation took place before quartz emplacement and mineralization. In the first case, right-lateral movement in the shear zone would have formed a northeast-trending foliation that truncated and isolated the preexisting regional foliation (fig. 8A), at the same time establishing the en echelon pattern in the northeast-trending foliation that subsequently controlled the emplacement of quartz veins. In the other case, a northeastward foliation would have formed and an en echelon pattern been developed by right-lateral movement as in the first case. Then a later minor deformation, which was resolved into left-lateral movement along the shear zone, would have caused a rotation of the foliation trend from northeast to north and an opening up or spreading of foliation surfaces. In effect, this rotation was a second folding, opposite in sense to that giving rise to the en echelon arrangement of veins (fig. 8B). The podlike shapes and slight S-form of many quartz veins and sheeting-bounded units within veins, as well as the internal pattern of some divergent seams and inclusions of schist as in figure 5E, are suggestive of such minor left-lateral movement. This deformation, and especially the opening or spreading of foliation that would have resulted from left-lateral movement, would have greatly facilitated the movement of solutions and the localization of veins in the shear zone.

The deposition of fluorite and metallic minerals, particularly huebnerite, commonly was localized both along sheeting and the divergent north-trending foliation seams in the veins. Sheeting and the divergent seams clearly were channelways by which the later (post quartz) hydrothermal solutions moved through the veins.

The tungsten mineralization may be related to a large westward bulge in the pluton, the bulge reaching from about 2 mi (3.2 km) north of the state line between North Carolina and Virginia to about 7 mi (11.2 km) south of the line (fig. 3). The 8-mile (12.8 km) long zone of known tungsten mineralization is within and virtually coextensive with the bulge. The concentration of mineralization in this area suggests that the bulge was a late phase of the plutonic intrusion. This part of the pluton probably was an area of unusual fracturing and shearing, with breaks trending mainly northeastward, northwestward, and north, judging by the trends of numerous quartz veins and long diabase dikes (Parker, 1963, pl. 2). The trends of major tungsten-bearing veins are disposed almost symmetrically with respect to the map outline of the bulge. The principal veins of the Hamme deposit, located a little south of midway along the bulge, trend northeastward, whereas the veins in the north part of the bulge—the Burwell, Jamieson, Kimball, and Taylor veins (Espenshade, 1947, pl. 1)—trend northwest. A few other mineralized veins trend about eastward. The principal veins trending northeastward and northwestward thus may correspond to planes of conjugate shearing. Mineralization may be present along other such zones in the pluton if they exist. Weathering and the lack of outcrops probably preclude the discovery of other shear zones by routine geologic mapping. Espenshade (1947, p. 11) noted that the shear zone occupied by the principal Hamme deposit might be related to a westward curve in the granite-schist contact, which is part of the edge of a small bulge a little south of midway along the large westward bulge described above (fig. 3). Other small and comparatively abrupt local bulges in the border of the pluton might mark the intersection of shear zones with the edge of the pluton. However, geochemical sampling has not yet detected any unusual concentrations of trace elements above such small bulges, one near the south end of the large westward bulge and others at the south-southeast end of the pluton.

ACKNOWLEDGEMENTS

John Windolph assisted in the mine mapping. Maps and sections of mine workings were provided by Ranchers Exploration and Development Corporation. The plotting of structural data in the equal-area projections (fig. 4) was greatly facilitated by computer programs provided by Michael Foose.

REFERENCES CITED

Butler, J. R., 1972, Age of Paleozoic regional metamorphism in the Carolinas, Georgia, and Tennessee southern Appalachians: Am. Jour. Sci., v. 272, no. 4, p. 319–333.

Butler, J. R., and Ragland, P. C., 1969, Petrology and chemistry of meta-igneous rocks in the Albermarle area, North Carolina slate belt: Am. Jour. Sci., v. 267, no. 6, p. 700–726.

Espenshade, G. H., 1947, Tungsten deposits of Vance County, North Carolina, and Mecklenburg County, Virginia: U.S. Geol. Survey Bull. 948–A, 17 p.

Fullagar, P. D., 1971, Age and origin of plutonic intrusions in the Piedmont of the southeastern Appalachians: Geol. Soc. America Bull., v. 82, no. 10, p. 2845–2862.

Glover, Lynn, III, Sinha, A. K., Higgins, M. W., and Kirk, W. S., 1971, U-Pb dating of Carolina slate belt and Charlotte belt rocks, Virgilina district, Virginia and North Carolina [abs.]: Geol. Soc. America Abs. with programs, v. 3, no. 5, p. 313.

Glover, Lynn, III, and Sinha, A. K., 1973, The Virgilina deformation, a late Precambrian to early Cambrian(?) orogenic event in the central Piedmont of Virginia and North Carolina: Am. Jour. Sci., v. 273–A, (Cooper volume), p. 234–251.

Hadley, J. B., 1973, Igneous rocks of the Oxford area, Granville County, North Carolina: Am. Jour. Sci., v. 273–A (Cooper Volume), p. 217–233.

Hills, F. A., and Butler, J. R., 1969, Rubidium-strontium dates for some rhyolites from the Carolina slate belt of the North Carolina Piedmont: Geol. Soc. America [Abs. for 1968,] Spec. Paper 121, p. 445.

Parker, J. M., 3d, 1963, Geologic setting of the Hamme tungsten district, North Carolina and Virginia: U.S. Geol. Survey Bull. 1122–G, 69 p.

St. Jean, Joseph, Jr., 1965, New Cambrian trilobite from the Piedmont of North Carolina [abs.]: Geol. Soc. America Spec. Paper 82, p. 307–308.

Stromquist, A. A., and Sundelius, H. W., 1969, Stratigraphy of the Albemarle Group of the Carolina slate belt in central North Carolina: U.S. Geol. Survey Bull. 1274–B, 22 p.

Sundelius, H. W., 1970, The Carolina slate belt, *in* Fisher, G. W., Pettijohn, F. J., Reed, J. C., Jr., and Weaver, K. N., eds., Studies of Appalachian geology: central and southern: New York, Interscience Publishers, p. 351–367.

Tobisch, O. T., and Glover, Lynn, III, 1971, Nappe formation in part of the southern Appalachian Piedmont: Geol. Soc. America Bull., v. 82, no. 8, p. 2209–2229.

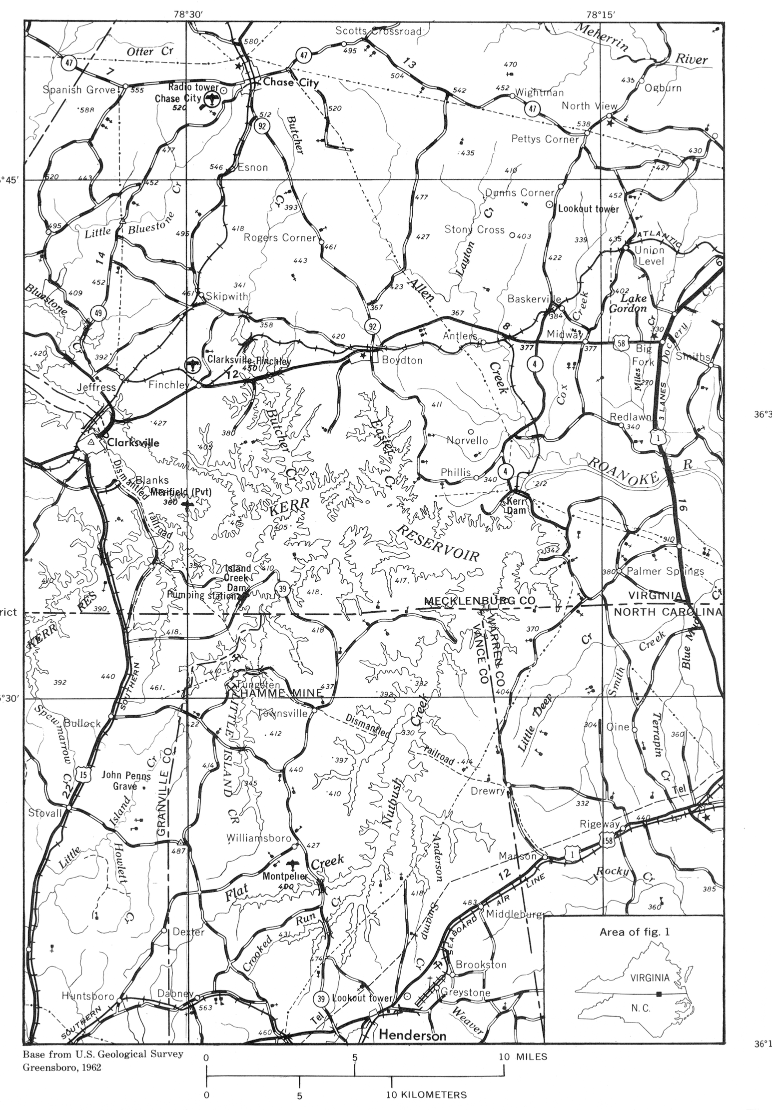


FIGURE 1.—Location map of Hamme (Tungsten Queen) mine, North Carolina.

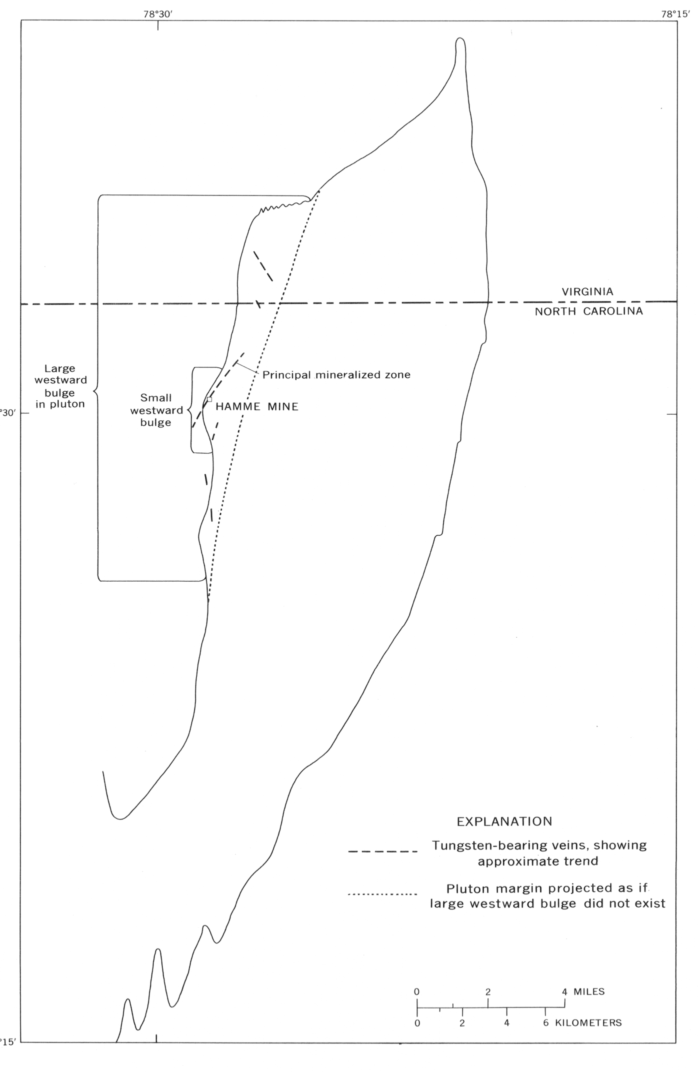


FIGURE 3.—Outline map of granodiorite-tonalite pluton, Hamme district, showing location and trends of tungsten-bearing veins and westward bulges in pluton. Modified slightly from Parker (1963, pls. 1 and 2).

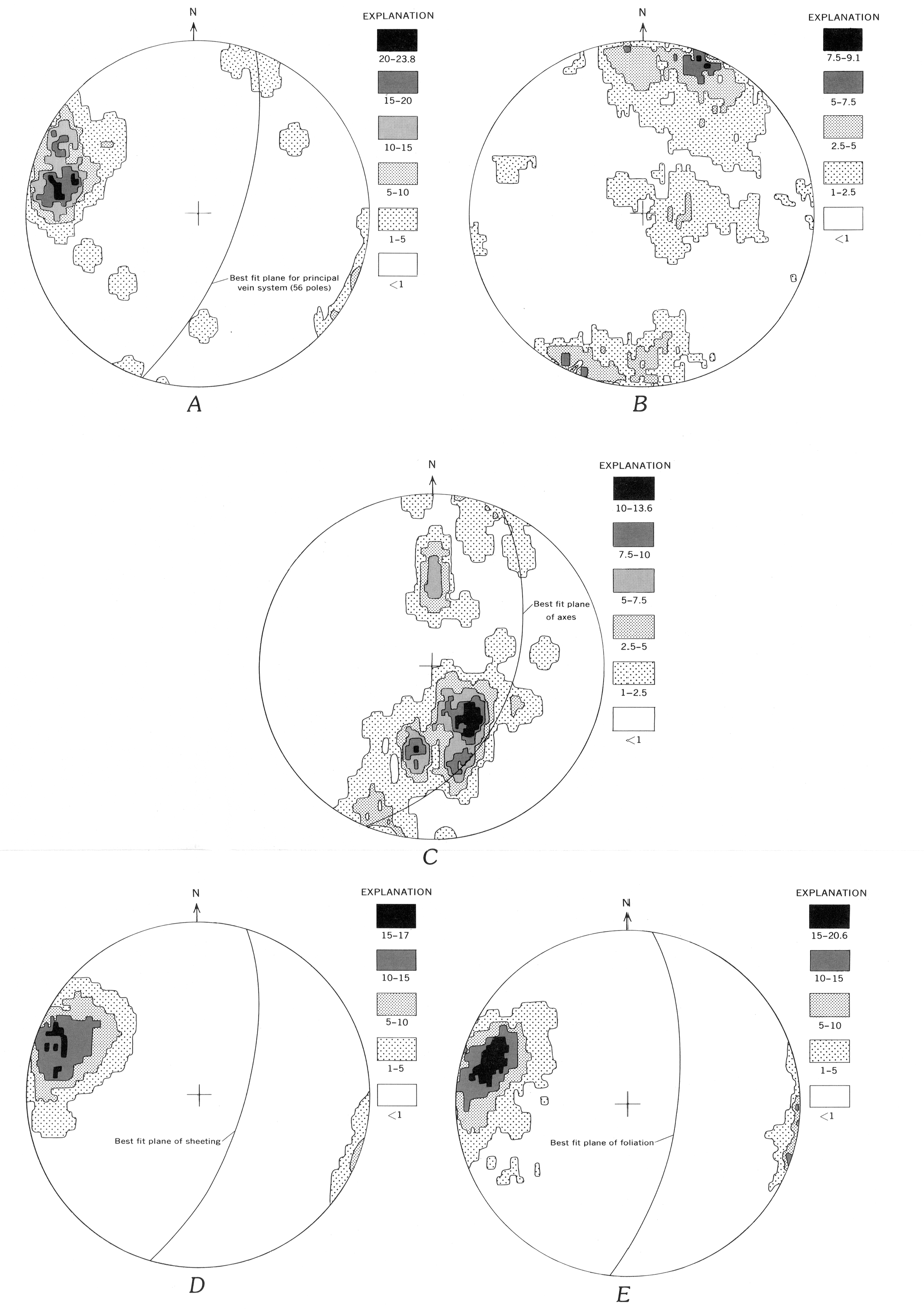


FIGURE 4.—Equal-area projections of vein and wallrock structures, Hamme mine. Patterns represent percentages of points (poles, axes) in 1-percent segments of diagram. *A*. 63 poles of vein walls. *B*. 341 poles of joints. *C*. 88 axes of folds in foliation, sheeting, and vein walls. *D*. 199 poles of sheeting. *E*. 131 poles of foliation.

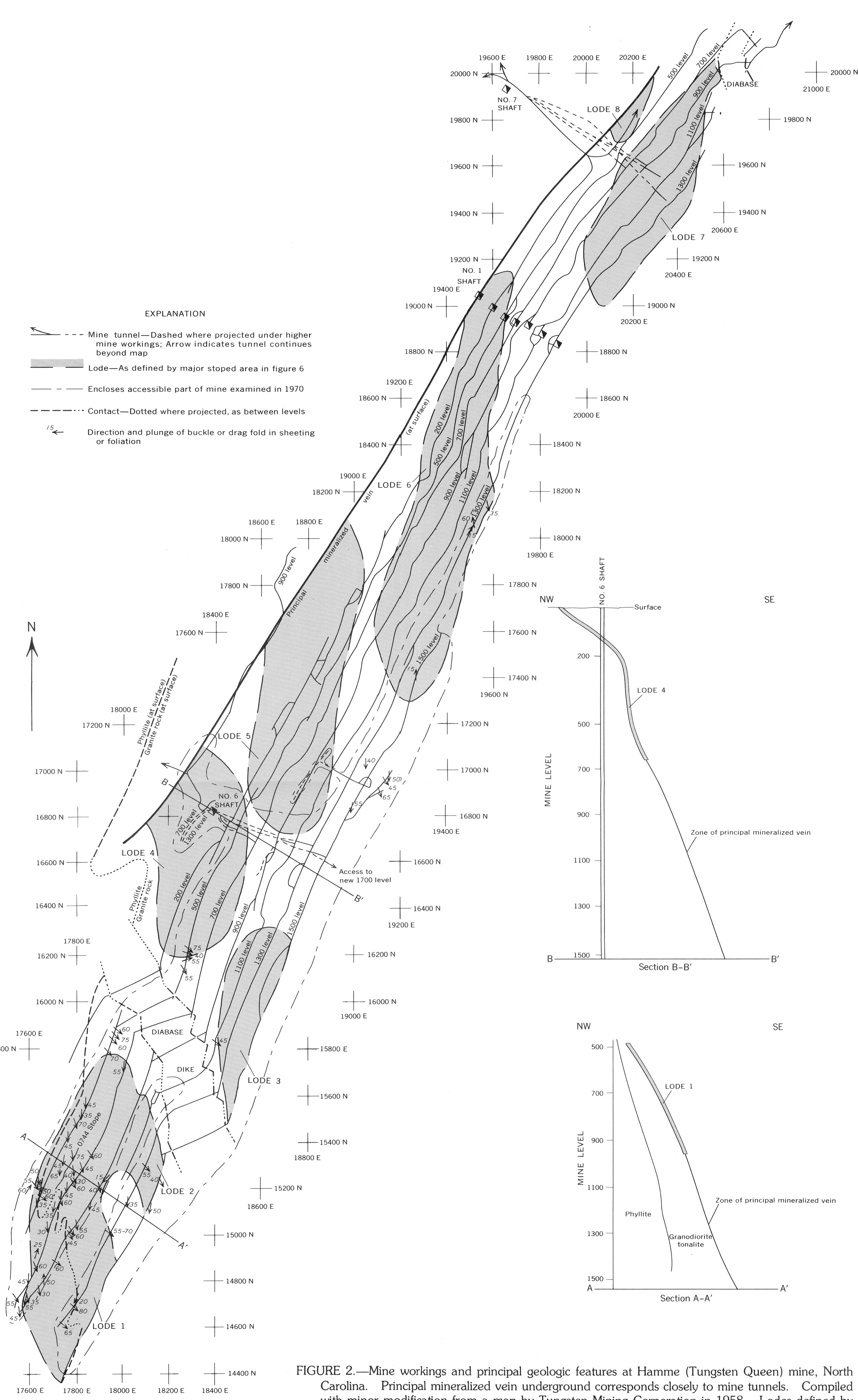


FIGURE 2.—Mine workings and principal geologic features at Hamme (Tungsten Queen) mine, North Carolina. Principal mineralized vein underground corresponds closely to mine tunnels. Compiled with minor modification from a map by Tungsten Mining Corporation in 1958. Lodes defined by stoped areas in longitudinal section were compiled in 1971 by Ranchers Exploration and Development Corporation (see fig. 6). Geology at the surface is from Espenshade (1947, pl. 2). Mine coordinates in feet north and east of arbitrary origin established by U.S. Bureau of Mines in 1943.

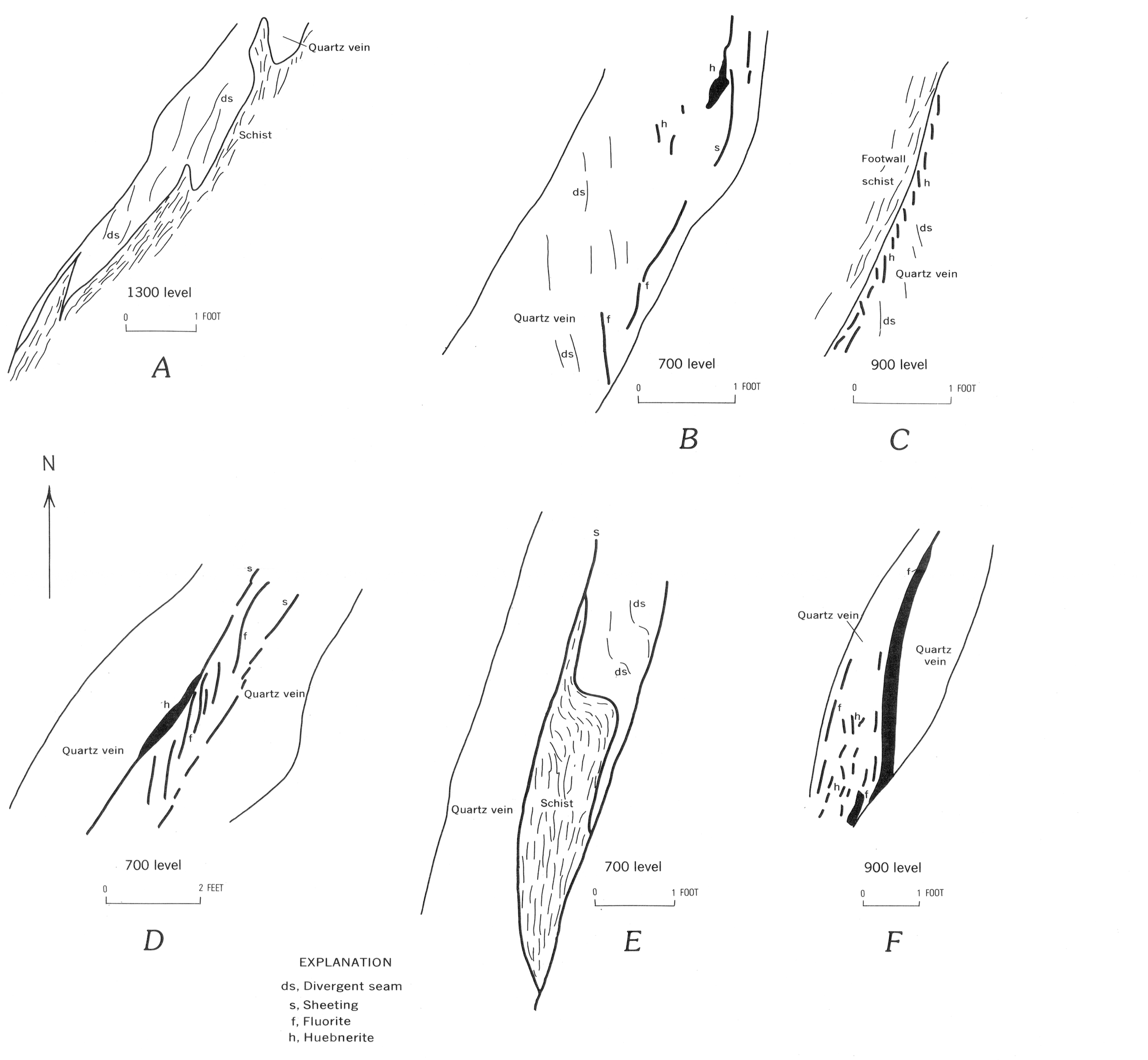
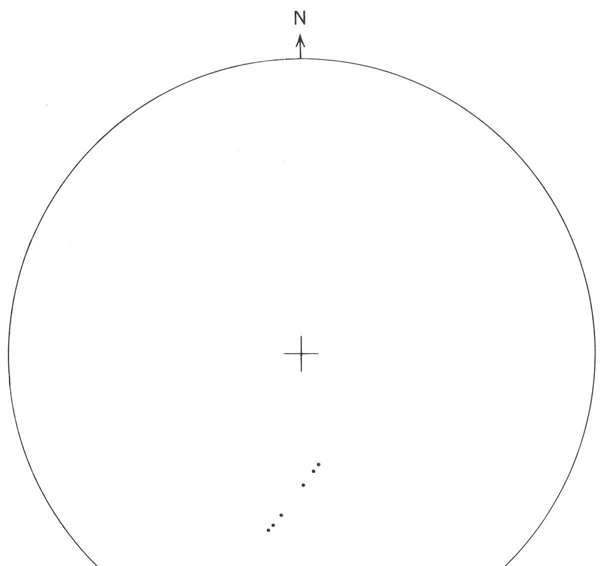


FIGURE 5.—Vein-schist relations. *A*. Extension of vein en echelon to the southwest: divergent schist seams angle northward across vein. *B*. Divergent schist seams trend northward across vein; huebnerite prisms alined parallel to divergent seams; fluorite lenses parallel to both sheeting and divergent seams. *C*. Footwall schist parallel to vein walls; huebnerite prisms within vein alined parallel to divergent seams which angle northward across vein. *D*. Fluorite veinlets alined northward across trend of quartz vein and sheeting, but merge into sheeting; huebnerite prisms concentrated along and parallel to sheeting. *E*. Small fold in schist pod in quartz vein, mimicked by divergent seams in vein; schist tails off into sheeting. *F*. Fluorite layer diverges across quartz vein; other fluorite seams parallel vein wall; huebnerite prisms alined both parallel to vein walls and divergently across vein.



Equal-area projection showing plunges of lodes in the plane of longitudinal section (fig. 6), rotated to an assumed dip of 70° SE.

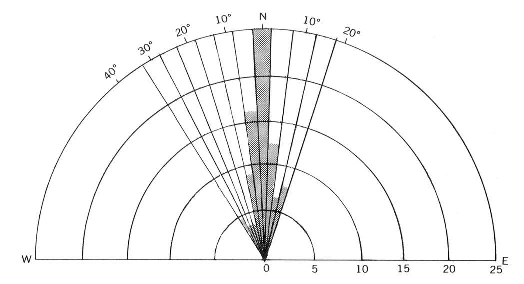


FIGURE 7.—Rose diagram of trends of divergent seams across mineralized veins, Hamme mine (80 values).

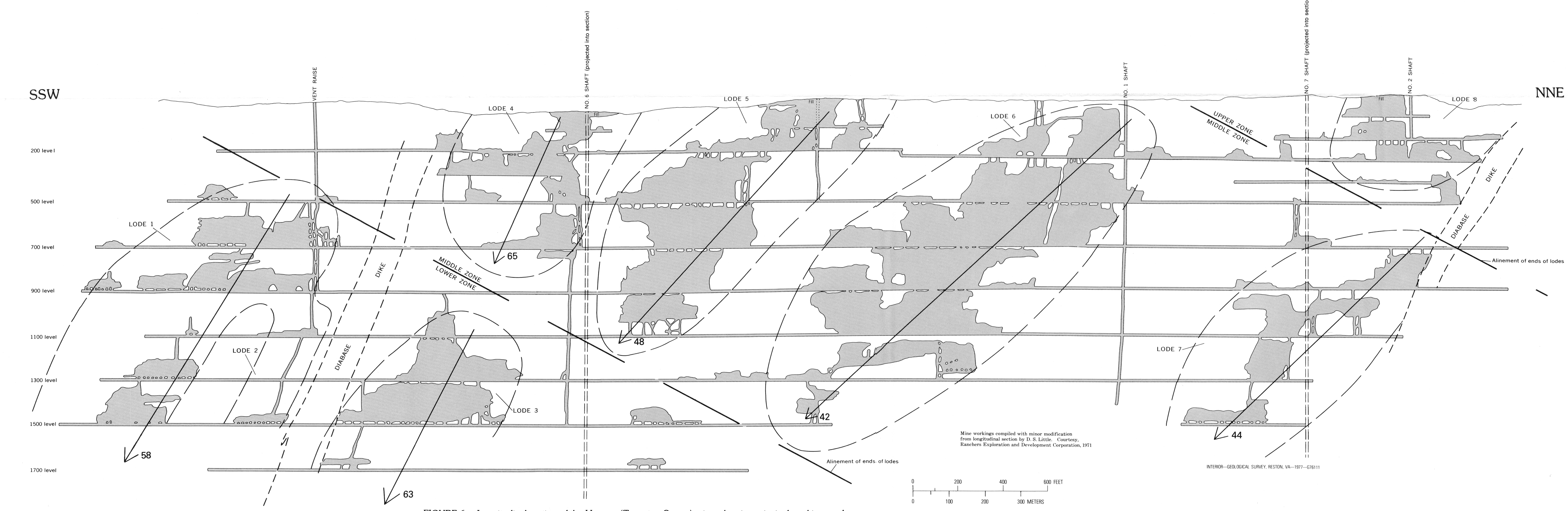


FIGURE 6.—Longitudinal section of the Hamme (Tungsten Queen) mine, showing principal workings and diabase dikes; major stoped areas (shaded) interpreted as representing eight lodes. Plane of section is N 28° E. Arrows show southwestward elongation and plunge of lodes. Alinement of ends of lodes define three northeast-dipping zones. Plunges of lodes have been projected to a vertical plane from the plane of principal vein.

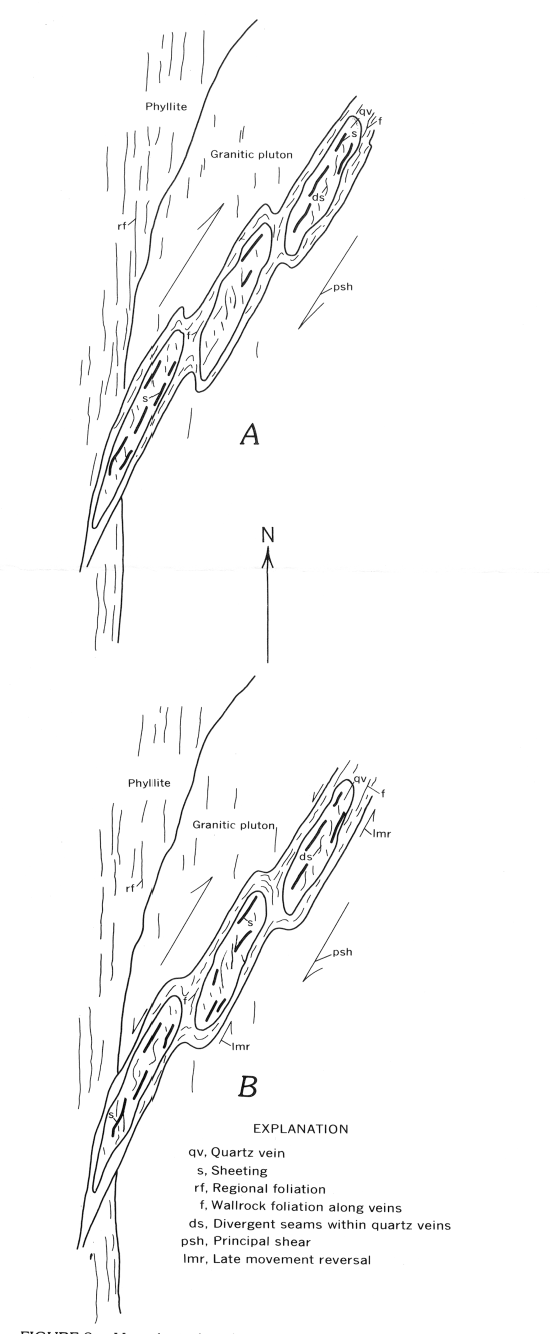


FIGURE 8.—Hypothetical explanations of vein structural patterns. *A*. Divergent seams are relicts of regional foliation. Northeast-trending shear zone truncates regional foliation. Younger (wall rock) foliation in shear zone is drag-folded as shown by en echelon arrangement of veins along shear zone. Vein walls, younger foliation, and sheeting are mutually conformable. *B*. Divergent seams are caused by late movement reversal. Northeast-trending shear zone completely obliterates regional foliation and initially contains only wall rock foliation parallel to shear zone, drag-folded into an en echelon pattern. Later, minor reversal of movement along shear zone causes buckling and spreading of foliation surfaces, and establishes the trend of divergent seams.

MAPS AND DIAGRAMS SHOWING STRUCTURAL CONTROL OF THE HAMME TUNGSTEN DEPOSIT, VANCE COUNTY, NORTH CAROLINA

By Jacob E. Gair
1977

For sale by Branch of Distribution, U.S. Geological Survey, 1200 South Eads Street, Arlington, VA 22202