MAP GQ-1073

DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

GEOLOGIC MAP OF THE INDIAN HILLS QUADRANGLE, JEFFERSON COUNTY, COLORADO

By Bruce Bryant, Robert D. Miller
and Glenn R. Scott

GEOLOGIC QUADRANGLE MAP
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BRYANT AND OTHERS—GEOLOGIC MAP OF INDIAN HILLS QUAD., CO 1:24,000 MAP GQ-1073

GEOLOGIC MAP SYMBOLS

COMMONLY USED ON MAPS OF THE UNITED STATES GEOLOGICAL SURVEY

(Special symbols are shown in explanation)

Contact – Dashed where approximately located; short dashed where inferred; dotted where concealed

Contact – Showing dip; well exposed at triangle

Fault – Dashed where approximately located; short dashed where inferred; dotted where concealed

Fault, showing dip – Ball and bar on downthrown side

Normal fault – Hachured on downthrown side

Fault – Showing relative horizontal movement

Thrust fault – Sawteeth on upper plate

Anticline – Showing direction of plunge; dashed where approximately located; dotted where concealed

Asymmetric anticline – Short arrow indicates steeper limb

Overturned anticline – Showing direction of dip of limbs

Syncline – Showing direction of plunge; dashed where approximately located; dotted where concealed

Asymmetric syncline – Short arrow indicates steeper limb

Overturned syncline – Showing direction of dip of limbs

Monocline – Showing direction of plunge of axis

Minor anticline – Showing plunge of axis

Minor syncline – Showing plunge of axis

Strike and dip of beds – Ball indicates top of beds known from sedimentary structures

Inclined Horizontal

Vertical Overturned

Strike and dip of foliation

Inclined Vertical Horizontal

Strike and dip of cleavage

Inclined Vertical Horizontal

Bearing and plunge of lineation

Inclined Vertical Horizontal

Strike and dip of joints

Inclined Vertical Horizontal

Note: planar symbols (strike and dip of beds, foliation or schistosity, and cleavage) may be combined with linear symbols to record data observed at same locality by superimposed symbols at point of observation. Coexisting planar symbols are shown intersecting at point of observation.

Shafts

Vertical Inclined

Adit, tunnel, or slope

Accessible Inaccessible

Prospect

Quarry

Active Abandoned

Gravel pit

Active Abandoned

Oil well

Drilling Shut-in Dry hole abandoned

Gas Show of gas

Oil Show of oil

GEOLOGY OF THE INDIAN HILLS QUADRANGLE, JEFFERSON COUNTY, COLORADO

By Bruce Bryant, Robert D. Miller, and Glenn R. Scott

GEOLOGY OF THE PRECAMBRIAN ROCKS

Precambrian rocks, which make up the southwestern two-thirds of the Indian Hills quadrangle, are mainly metamorphic rocks that lie between the 1,700-m.y.-old Boulder Creek batholith to the north and the 1,040-m.y.-old-Pikes Peak batholith to the south. (See index map, main map.) The Floyd Hill fault zone, one of many northwest-trending fault zones in the Front Range, bisects the quadrangle and splays out southeastward in the quadrangle.

The Precambrian rocks of this quadrangle have been mapped previously only at small scale or in reconnaissance (Boos and Aberdeen, 1940; Boos, 1954; Boos and Boos, 1957; Scott, 1961). More detailed studies of adjacent quadrangles to the north (Gable, 1968), east (Scott, 1962), southeast (Scott, 1963), and south (Peterson, 1964) have recently been published. Geochronologic and isotopic studies (Hedge and others, 1967; Hedge, 1969) allow the general history of the Precambrian rocks to be outlined, though details of stratigraphy and structure remain obscure.

The sedimentary rocks and surficial deposits have been described adequately in several of the above reports, for instance Scott (1962, 1963); therefore, we have limited our discussion of them to an expanded map explanation.

The Precambrian rocks of the Indian Hills quadrangle originally were layered sedimentary and volcanic rocks, probably deposited in an island-arc environment a few hundred million years before they were complexly deformed at least twice and were metamorphosed to high grade about 1,750-1,700 m.y. ago (Hedge, 1969). During the metamorphism, rocks of the entire area underwent incipient migmatization; in the southwestern part of the quadrangle, however, well-developed migmatites formed. Many pegmatites formed. Locally numerous small pods and lenses of granodiorite were emplaced in the biotite gneiss near the well-developed migmatite. Field relations suggest that local recrystallization or melting of the gneiss may have been the mechanism of their emplacement. Larger bodies, such as the crosscutting body in the center of the quadrangle, were intruded from an unknown depth. Deformation and metamorphism continued after emplacement of the granitic bodies.

At about 1,440 m.y. ago, dikes and small irregular plutons of Silver Plume Quartz Monzonite were emplaced in the western part of the quadrangle. Pegmatites also were emplaced at this time; but in the field, as indicated by Hedge (1969), it is not possible to tell the difference between pegmatites of this age and pegmatites of other ages. Dikes of unfoliated lamprophyre were emplaced after the 1,700- to 1,750-m.y.-old metamorphism, but their age relations with the muscovite-biotite quartz are not known.

Faulting along north-to-west trends occurred at various times over a period ranging from perhaps about 1,700 m.y. ago to Late Cretaceous or Paleocene.

The metamorphic rocks are listed in the map explanation in a tectonic sequence because no unquestionable stratigraphic criteria for tops or bottoms were recognized. The lowest metamorphic rocks are the rutile-bearing sillimanite quartzite and associated rocks exposed in the core of a dome in Turkey Creek Canyon in the eastern part of the area of Precambrian rocks. These exposures are overlain by felsic gneisses, many of which are rich in plagioclase and which contain layers of biotite-hornblende gneiss and amphibolite, as well as plagioclase-quartz-microcline gneiss. These in turn are overlain by microcline-rich felsic gneiss of granitic aspect containing sparsely distributed finer grained and less microcline-rich layers. Even the coarsest grained, most granitic-appearing felsic gneiss is characterized by rather fine grained (<0.5 mm) biotite. When viewed from a distance, these rocks on the south slope of Turkey Creek Canyon have a grossly layered structure that is not apparent in most single outcrops. The microcline-rich felsic gneiss is overlain by a thin unit of garnet-mica gneiss containing layers rich in coarse-grained garnet. This in turn is overlain by a unit of amphibolite and quartzite that contains calc-silicate quartzite and gneiss, which is overlain by biotite gneiss and schist containing muscovite and, in many places, sillimanite. In the southern part of the quadrangle, the same general sequence of rock types is found outward from another domal structure, except that the thin garnet-rich unit is lacking. Within this dome, however, are plutonic rocks and migmatites, as well as layered felsic gneiss. The contacts between the rock units in the southern dome are gradational, but the more microcline-rich gneisses of the felsic gneiss unit here are concentrated just beneath the thin amphibolite unit as they are in the northern dome.

Between the domes a horseshoe-shaped area of amphibolite, quartzite, and marble crops out. This unit differs from that adjacent to the felsic gneiss around the domes by having less amphibolite and more marble, quartzite, and mica schist and gneiss. If the unit were stratigraphically equivalent to the amphibolite adjacent to the domes, it would form a westward-plunging antiform and would probably be underlain by felsic gneiss. However, it actually forms an overturned synform, and biotite gneiss and schist rather than felsic gneiss occur inside the horseshoe-shaped area of outcrop. Thus, on the basis of rock type and rock sequence, the amphibolite, quartzite, and marble in that area must be a tectonically, and perhaps stratigraphically, higher unit than the one surrounding the gneiss dome.

Uncertainty exists concerning the exact location of the contacts of the amphibolite, quartzite, and marble unit in some areas, such as just south of Docmann Gulch at the mountain front. Whether this uncertainty is due to stratigraphic intercalations of biotite gneiss and schist or to minor folds along the contact is not known.

CORRELATIONS OF ROCK UNITS WITH THOSE IN ADJACENT QUADRANGLES

The felsic gneisses of the Indian Hills quadrangle are equivalent to the units in the Morrison quadrangle to the north designated by Gable (1968) as mottled migmatitic microcline-quartz-plagioclase-biotite gneiss (gnmm) and gneissic granodiorite (gg); the more plagioclase-rich gneiss in Turkey Creek Canyon is equivalent to the granitic microcline-quartz-plagioclase gneiss (gnm) and the quartz-plagioclase gneiss (gnq) designated by Gable. To the south, the granitic gneiss of the Platte Canyon quadrangle (Peterson, 1964) is equivalent to three of the units in the Indian Hills quadrangle: felsic gneiss, migmatite, and gneissic quartz monzonite and granodiorite. Biotite-muscovite granite (gb) of the Kassler and Littleton quadrangles (Scott, 1962, 1963) is equivalent to rocks designated herein as gneissic quartz monzonite and granodiorite and as migmatite where the Kassler and Littleton quadrangles adjoin the Indian Hills.

STRUCTURE

The apparent succession of rock units based on map pattern indicates that east of the Floyd Hill fault zone steep-sided domes of felsic gneiss occur at each end of the quadrangle; these are separated by an east-plunging overturned syncline. West of the Floyd Hill fault zone in the southern part of the quadrangle, two doubly plunging synclines trend north-south and have gentle plunges.

The southern dome is obscured apparently by a terrane of migmatite and granitic rock south of the Indian Hills quadrangle (Peterson, 1964; Scott, 1963). To the north, the northern dome is obscure also, partly because marker layers were not found that would delineate it in the Morrison quadrangle (Gable, 1968).

Trends of the major structural features north of the gneiss dome in the Morrison quadrangle (Gable, 1968) and in the Ralston Buttes quadrangle (Sheridan and others, 1967) are approximately east-west like those between the gneiss domes in the Indian Hills quadrangle. To the south, Peterson and Scott (1960) interpret the major structural features to consist of N. 80° W.-trending isoclinal folds. This contrasts with the north-south folds west of the Floyd Hill fault zone in the Indian Hills quadrangle and may indicate a change across the fault in Bear Gulch in the Platte Canyon quadrangle, but migmatization has obscured the rock sequence in that area so that the relations between the folds of different trends of the Indian Hills quadrangle and those of the area to the south cannot be determined.

The area of Precambrian rock exposures in the Indian Hills quadrangle was divided into 10 areas (fig. 1) for a detailed study of minor structural features. Equal-area plots summarizing orientations of minor features of the scale observed in individual outcrops (fig. 2) show that those features are unrelated

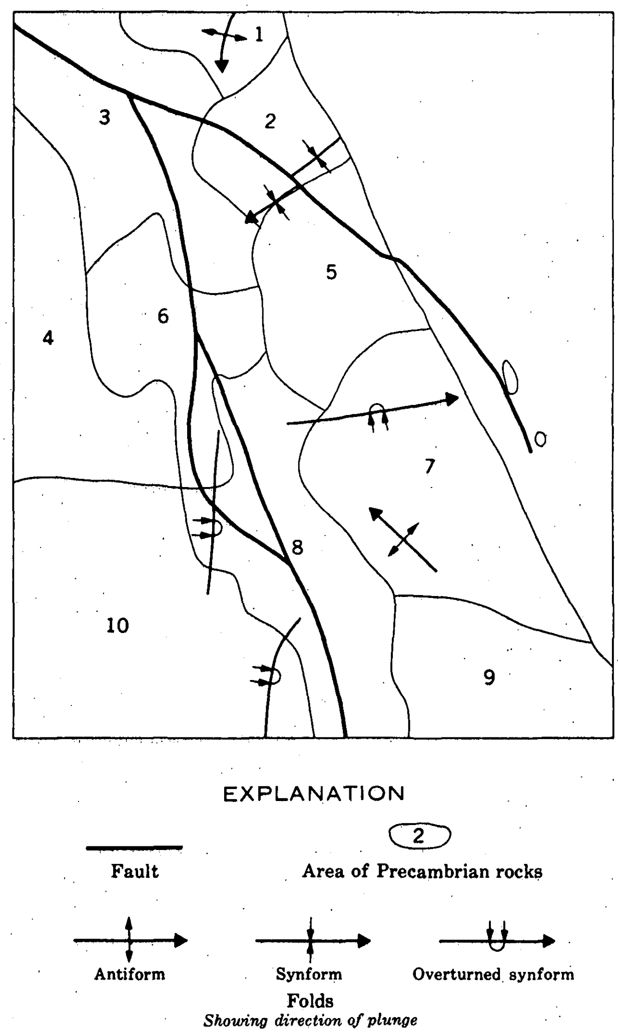


FIGURE 1.—Sketch map of the Indian Hills quadrangle showing major faults and folds and numbered areas of Precambrian rocks for which minor structural features were compiled (figure 2).

to the major folds mentioned above. For instance, in area 7, the lineation (diagram 7B, fig. 2), which consists of minerals alined parallel to the axes of minor folds, plunges west in the opposite direction from the major syncline. This west-plunging lineation is at the pole of a girdle formed by the foliation (diagram 7A, fig. 2). Axes of minor folds (diagram 7C, fig. 2) form a concentration parallel with the lineation, though there is more scatter than shown by the lineation. In area 8, where mapping indicates major gently plunging folds, the lineation is vertical or plunges steeply north, also close to the axis of a girdle formed by the foliation. Such relations show that the minor structural features are the result of a deformation unrelated to the earlier large-scale folding. In area 10, the major folds trend north-south and have gentle plunges, but the lineations plunge quite steeply north and northeast (diagram 10B, fig. 2) like those measured by Peterson (1964) to the south. To the southeast, cornering on area 9, Scott (1963) finds that lineations formed by axes of minor folds and alined minerals summarized on an equal-area plot produce two maxima—one trending N. 80° W. which is considered to be parallel with the major folds and one at N. 20° E. parallel with the statistical high of Peterson (1964) and the statistical high shown in diagram 10B. The N. 20° E. lineation was considered by Scott to be an *a* lineation of the major folds. In the Indian Hills quadrangle, northeast-trending lineation is interpreted as a *b* lineation parallel with the axes of minor folds that were formed later than the major folds. It is difficult to reconcile the two interpretations; perhaps the steeply plunging N. 20° E. folds were formed during the later deformation that is recognized in the Indian Hills quadrangle. No systematic steepening of foliation and lineation is obvious as the Pikes Peak batholith is approached in either the Platte Canyon or the Kassler quadrangles; therefore, the moderately steep plunges of the N. 20° E. lineations are not due to deformation by intrusion of that batholith.

In area 3, adjacent to the Morrison quadrangle, similar relations among foliation girdle data, lineation data, and sparse minor fold data (diagrams 3A, B, and C, fig. 2) are found. The lineations have somewhat the same orientation as those found by Gable (1968, fig. 5) to the north. Both her data (Gable, 1968, fig. 6) and those given here show that these lineations formed during or after the emplacement of the gneissic quartz monzonite and granodiorite which was probably emplaced at the time of the Boulder Creek batholith.

METAMORPHISM

Brief petrographic study indicates that the rocks of the Indian Hills quadrangle were metamorphosed under the conditions of the sillimanite zone. Assemblages that contain contemporaneous muscovite and sillimanite are widespread. Only one sample of sillimanitic schist contained microcline, and in this, the microcline was concentrated in thin pegmatitic veinlets. The sample came from a locality adjacent to the area of migmatite in the southwestern part of the quadrangle. The high-grade metamorphism characterized by sillimanite and muscovite probably occurred during the deformation that was responsible for the minor folds and lineations discussed above, because such minerals as hornblende and sillimanite form the lineations in these minor folds.

During this metamorphism, widespread pegmatitic and granitic lenses, layers, and pods formed throughout the metamorphic rocks; and in the southwestern part of the quadrangle, granitic material intimately interlayered with the metamorphic rocks constitutes a major part of the rock. In that area mappable homogeneous bodies of granitic rock were emplaced by either local melting of the migmatites or intrusion from below the level of present exposure. Also, at this same time fluorine metasomatism of the rutile-bearing sillimanite quartzite may have occurred to produce the topaz found in it (D. M. Sheridan, oral commun., 1970).

Both Scott (1963) and Peterson (1964) reported the widespread occurrence of microcline in sillimanite-bearing rocks in the migmatitic terrane south of the Indian Hills quadrangle. Descriptions by Scott (1963, p. 75) suggest that rocks of the Kassler quadrangle may contain some muscovite contemporaneous with the sillimanite and microcline. Sheridan (in U.S. Geol. Survey, 1966, p. A78-A79) reported contemporaneous sillimanite, muscovite, and microcline northwest of the Indian Hills quadrangle. On the other hand, Gable (1968) reported that the rocks of the Morrison quadrangle north of Indian Hills all are metamorphosed to sillimanite-potash feldspar grade and that main-assemblage muscovite is very sparse. However, her petrographic data (Gable, 1965, table 2) suggest that the rocks in the Bear Creek area in the southern part of the quadrangle contain sillimanite and muscovite and lack microcline. Sheridan, Maxwell, Albee, and Van Horn (1967, p. 37-38) pointed out the general lack of microcline in association with sillimanite and muscovite in the Ralston Buttes quadrangle, a situation similar to that in the Indian Hills quadrangle. These variations suggest that the regional distribution of rocks of the sillimanite-muscovite and sillimanite-microcline zones in the Front Range can possibly be delineated.

FAULTS

The Floyd Hill fault system bisects the Precambrian rocks of the Indian Hills quadrangle. The fault zone is less than 1 mile wide at the community of Indian Hills in the northwest corner of the quadrangle, and it splays out into a number of widely separated faults to the south and southeast.

The fault zones are composed of fractured and brecciated rocks that tend to form saddles and valleys. Consequently, the zones are poorly exposed. The width of the fractured zones ranges from a few feet to a few hundred feet, and within parts of the wide zones, lenses of less fractured rock may be found.

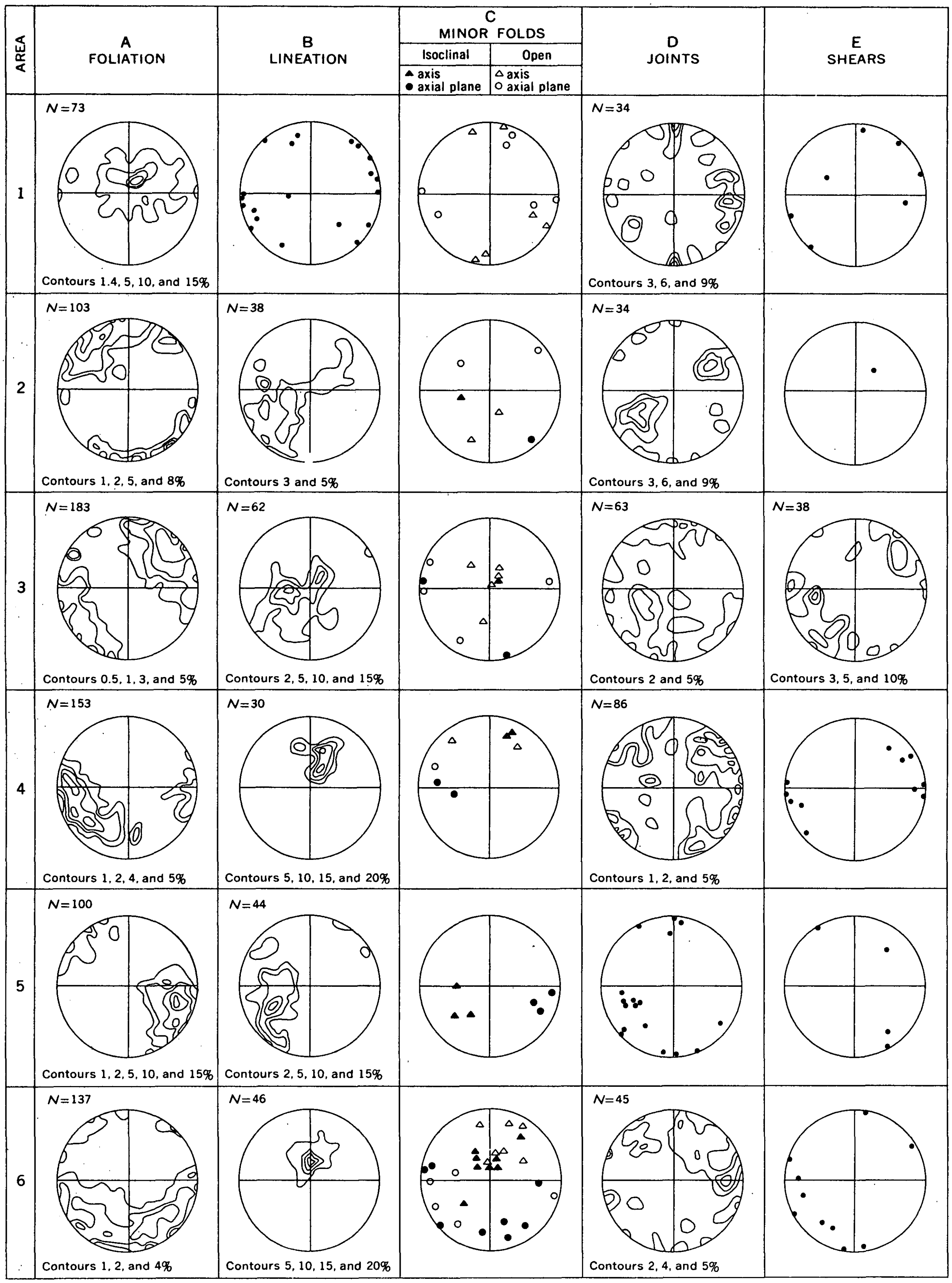
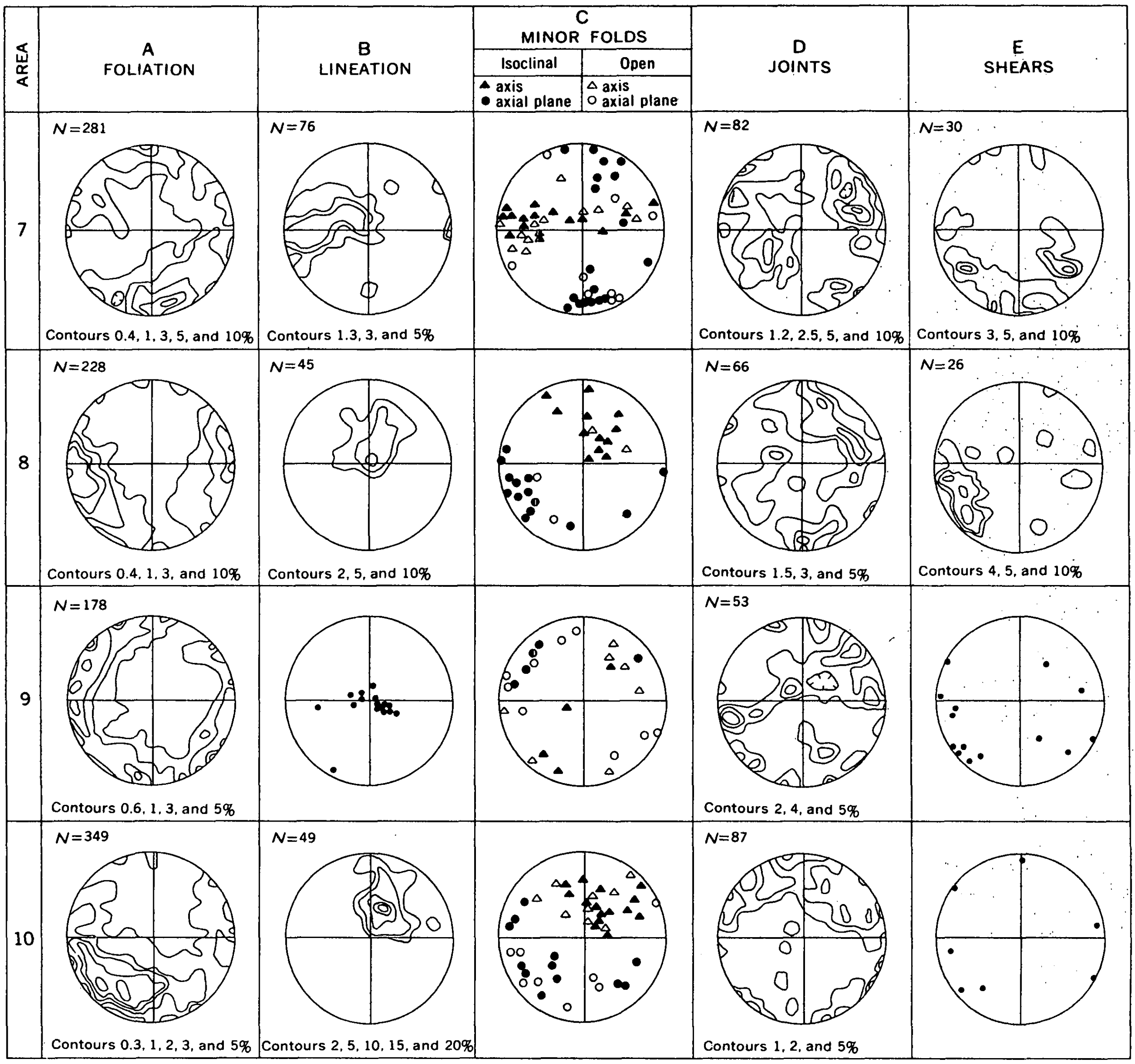


FIGURE 2. (Above and facing pages).—Orientation of minor structural features in the Precambrian rocks of the Indian Hills quadrangle. All diagrams are equal-area projections on the lower hemisphere with plane of projection horizontal and north at the top. Contours show percentage of points falling within 1 percent of area of diagram. N=number of points.



No detailed study of the mineralogy of the fault zones was made, but iron oxide and clay minerals are evident in some. Evidence of silicification is generally absent. Where some faults are parallel with foliation and layering in the mica schist and gneiss, such as along the fault between Fenders and Van Alderstien Gulch, effects of faulting consist mainly of a silvery sheen on some foliation planes owing to shearing and recrystallization of fine-grained mica and chlorite along them.

The distribution of mafic granodiorite and quartz diorite intrusives along one strand of the fault zone west of Tiny Town and west of Bald Mountain suggests that a break may have existed there about 1,700 m.y. ago which controlled the emplacement of those intrusives. Hutchinson and Hedge (1967) suggested that there was left-lateral movement along that fault. Movement along the various splits of the Floyd Hill fault zone after emplacement of the elongate body of gneissic quartz monzonite and granodiorite northwest of Massey Draw totals several thousand feet in an apparent left-lateral sense. Apparent left-lateral displacement on the Ken Caryl fault is 1,200 feet for both that intrusive and the margin of the gneiss dome of Turkey Creek Canyon. However, the presence of the amphibolite-quartzite-marble unit (aqm) tectonically above the biotite gneiss unit (gnb) east of the fault near the mountain front and its absence from the west side suggests that there was a component of dip-slip movement, with down on the east side. In post-Fountain time the east side of the Ken Caryl fault moved up several hundred feet. Apparent displacements become less to the south and southeast on the various branches of the fault system. A system of faults in the southeastern part of the quadrangle has small apparent displacements predominantly in a left-lateral sense.

Probably most of the strike-slip movement along the northwest-trending faults took place after the uplift and cooling that followed the intrusion of the Silver Plume Quartz Monzonite 1,440 m.y. ago and before deposition of the Pennsylvanian sediments. The fracturing and brecciation along the faults must have taken place after regional uplift and cooling after micas became closed systems which occurred during the time between the intrusion of the Silver Plume Quartz Monzonite 1,440 m.y. ago and the Pikes Peak batholith 1,040 m.y. ago as indicated by K-Ar ages in the region (Peterman and Hedge, 1968). Only locally do the rocks along the northwest-trending fault zones display evidence of recrystallization during or after shearing.

The Ken Caryl fault and a fault zone at Brush Creek in the southeast corner of the quadrangle displace the Fountain Formation of Pennsylvanian and Permian age. The direction of movement was predominantly dip slip with the east side up about 500 feet on the Ken Caryl fault and about 800-1,000 feet on the fault by Brush Creek. The Ken Caryl fault disappears on the west side of the Deer Creek anticline south of Deer Creek. Lack of displacement of east-west-trending units in Precambrian rock exposed in the Deer Creek anticline east of the Ken Caryl fault from the same units west of the fault north of Docmann Gulch probably suggests either that (1) Precambrian strike-slip movement died out this far south or (2) this part of the fault is a post-Pennsylvanian feature and the main Precambrian fault is concealed beneath the sedimentary rocks east of the Deer Creek anticline.

The faults in the Brush Creek area are splits off the strike fault mapped in the Fountain Formation in the Kassler quadrangle (Scott, 1963). That fault dies out 1 mile inside the Indian Hills quadrangle where it lies along the Precambrian-Pennsylvanian contact.

JOINTS

Most of the joints (column D, fig. 2) have a north to northwest trend which is independent of the orientation of the major and minor folds but is related to a regional fracture pattern reflected by northwest-trending faults and shears shown on the map and found in outcrop (column E, fig. 2) and by the N. 30° W. trend of the east margin of the Front Range in the Indian Hills quadrangle. In areas along the margins of the Precambrian, such as 2 and 7, northwest-trending joints have northeast dips parallel to the old Precambrian land surface on which Pennsylvanian rocks were deposited (diagrams 2E and 7E). These may have been extensional joints caused by expansion during erosional unloading. They are accompanied by a second set with a northwest trend but a southwest dip; these joints may have been steeply dipping before Laramide uplift of the Front Range and would be longitudinal joints in relation to the trend of the late Paleozoic Front Range Highland and parallel with the northwest-trending faults initiated during the Precambrian. In areas 2, 5, and 7, the more gently plunging lineations, indicated by smearing out of the maxima (column B), might have been caused by rotation along the margin of the Front Range during Laramide uplift. In a few areas, such as 4, 8, and 10, northeast-trending regional crossjoints dip steeply.

MINERAL RESOURCES

About 100 prospects and small mines were found during mapping of the Precambrian rocks. Many of them are in pegmatite. The best known and most productive mine in the quadrangle is the Bigger mine, at the head of Switzers Gulch, where feldspar, scrap mica, and beryl were produced in the late 1880's, the late 1930's, and the early 1940's. This pegmatite also contains tourmaline, garnet, bismuthite, bismuthinite, columbite, and monazite (Hanley and others, 1950; Boos, 1954). Small amounts of mica or beryl may have been shipped from other mines in pegmatites of the area, but many of the openings on pegmatite are only prospects. In some, sheet mica several inches in diameter had been separated but not sold, probably because it is ruled and stained.

Other prospects are mostly on rusty-weathering calc-silicate rocks; others are on shears. Most are apparently barren, but a few show small quantities of malachite, chalcopyrite, and galena. Semiquantitative spectrographic analyses of selected samples of the most mineralized material from dumps of these prospects revealed that a few rocks contain as much as 2 percent Cu, 1.5 percent Pb, 2.0 percent Zn, 3 oz per ton of silver and a trace of gold. No production of metals from the Indian Hills quadrangle has been recorded.

Biotite gneiss and schist have been quarried for road metal in and near fault zones just north of the mouth of Iowa Gulch and in Van Alderstien Gulch. There rocks at present are being quarried in Wildcat Gulch for construction purposes.

ENGINEERING GEOLOGY CONSIDERATIONS

Much of the rock near the surface in the Indian Hills quadrangle is weathered, except in the major canyons and in the small gorges through the abrupt east scarp of the area of Precambrian rocks. Pegmatites are most resistant to weathering, and the persistence of abundant but detached pegmatite fragments in the soil makes it difficult to map pegmatites accurately on the basis of float. Next most resistant is the Silver Plume Quartz Monzonite. The felsic gneiss and the gneissic quartz monzonite and granodiorite weather more easily. The most deeply weathered rock types are mafic granodiorite and quartz diorite. Saprolite derived from these rocks is as much as 30 feet thick where exposed in roadcuts for U.S. Highway 285 south of Indian Hills. Accuracy of prediction of depth of weathering at any given locality is uncertain inasmuch as outcrops of nearly fresh rock may be found even in areas of gentle topography where, commonly, the rock is more deeply weathered. Nevertheless, outside the steep-sided canyons, roads of normal subdivision width have been constructed almost everywhere without blasting.

The fault and fracture zones are characterized by fractured rock in which valleys and saddles have formed. The fractured rock is easy to excavate, but deep cuts are not likely to stand as well as those made outside the fault zones.

The most important structural element in the Precambrian rocks from both a practical and a scientific point of view is the foliation. The rocks tend to break along the foliation planes, especially where incipient weathering has occurred within a few tens of feet of the surface. The orientation of the foliation planes can affect the ease of excavation and the design of large cuts. Undercutting of the foliation planes, especially at the base of a steep slope, encourages sliding and slumping of rock masses above them, which if planned is advantageous; if not planned it can be disastrous. Such sliding has occurred, and probably is occurring, along lower Turkey Creek Canyon. In some areas, such as area 5 (diagram 5A, fig. 2), the attitude of the foliation is quite uniform and predictions of its attitude at any specific locality can be made, but in others, such as area 6 (diagram 6A, fig. 2), predictability is uncertain. On-site studies for each major excavation should be made. Joints are widespread in the rocks, but they are not as closely spaced as the foliation planes. Single joint planes, however, are more likely than foliation to maintain their attitude over large distances in areas where the foliation is not uniform.

The areas of greatest landslide potential are in lower Turkey Creek Canyon. Foliation and layering in places dip slightly to moderately toward the creek, and undercutting by stream erosion and highway construction have resulted in potentially unstable slopes. Just north of the exposures of sillimanitic quartzite, scarps as much as 9 feet high have formed as a result of incipient sliding since construction of the four-lane highway about 10 years ago. Along the steep slope at the east margin of the Precambrian rocks some landslides have moved along northeast-dipping joints. These joints are approximately parallel to the old land surface on which the Fountain Formation was deposited. They were tilted during uplift of the Front Range so that they dip at angles just slightly steeper than the slope (see diagrams 2D and 7D, fig. 2). Deep cuts into that slope would tend to promote landsliding along those joints.

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