PALEOZOIC SOUTH LOWER NORTH FORK CANYON
NORTHERN INDEPENDENCE RANGE,
ELKO COUNTY, NEVADA

by

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INTRODUCTION

The Problem

A triangular-shaped exposure of Cambrian and Carboniferous argillite, calcisiltite, calcarenite and chert sequences, separated by an unconformity, was discovered in the summer of 1955 by Professor Marshall Kay, in the northern Independence Mountains. This area of approximately nine square miles is surrounded by a terrane of cherts, quartzites, volcanics and greywackes. During the summer of 1958, Widmier (1960) mapped the portion of the triangle north of the North Fork of the Humboldt River.

The following summer, the author spent six weeks mapping the remaining area south of the North Fork, with the broad objective of determining the structure and stratigraphy. Deciphering the relationship of this carbonate eastern facies to the surrounding chert, turbidite and volcanic western facies, and exploring the ramifications of the unconformity have led to additional understanding of the tectonic history of the Basin and Range Province.

STRATIGRAPHY

General Statement

The rocks along the lower North Fork canyon were subdivided into two major groups (Widmier, 1960): 1) Formations A through D of Cambrian age, having a total thickness of about 3,500 feet; and 2) Formations E through I of upper Paleozoic age, having a total thickness of more than 4,000 feet. This subdivision is a natural one based on separation of Cambrian and Carboniferous rocks, by an angular unconformity, which will be discussed later in detail.

Mapping of the Paleozoics south of the lower North Fork Canyon, essentially corroborates the work of Widmier in regard to stratigraphy and to a lesser degree in structure. Every effort was made in the examination and interpretation of the southern Paleozoic terrane, to be independent and unbiased by consideration of Widmier's area to the north. Furthermore, autonomy was required in view of the complex stratigraphic and structural relationships.

Folding, faulting and facies changes over the area, combined with a lack of really distinctive units, resulted in difficulty in differentiation of mappable members as has been done by Widmier. To some extent this has required mapping many feet of varied sedimentary rock types as single formations and without accurate knowledge of the thickness involved. Where possible more detailed mapping was done for determination of the structure and estimation of original thickness and sequences of lithologies, which is essential to the reconstruction of past environment and tectonic history.

The eugeosynclinal chert sequence to the west and orthoquartzites to the south were studied only in reconnaissance for the resolution of structural relationships.

Cambrian Formations

Formation A

This formation consists of a greenish brown to olive argillite with fine gray to black argillaceous shale interbedded throughout. It is thinly laminated, non-fossiliferous and poorly exposed, being quite fissile.

The most prominent exposure is just north of the road at the canyon mouth at the base of Long Ridge on the northeast slope, at the border of the Humboldt National Forest. Two prominent, related sets of cleavage are exhibited and a third set is superimposed. There are two additional minor exposures at the base of the eastern slope of Long Ridge and on the southeast slope of Dry Canyon Ridge, just across Rim Canyon Creek from Big Spring. Both occurrences are the result of high angle faulting. The prominent exposure at the foot of Long Ridge was brought to its present position by a thrust fault, which extends south from Widmier's area to the north. In addition to the thrust fault at the base, this exposure is limited by a fault at its top, as the next stratigraphically higher formation - Formation B - is missing, and Formation C overlies Formation A. Thus, an estimation of the thickness of Formation A is impossible. The exposure here is of about 50 feet thick.

Widmier believes the argillite to be the oldest unit in the area for the following reasons: 1) the olive-gray argillite is lithically similar to argillite interbeds in Cambrian Formation D; 2) there are almost no argillites in the upper Paleozoic sequence; 3) it is basal in the thrust sheet and not observed within the Cambrian sequence elsewhere. The author agrees with Widmier's placement of Formation A but the evidence is not irrevocable.

There is still further cause for considering Formation A to be Cambrian and the oldest unit in the area. First, the occurrence of the two lesser exposures of Formation A indicate it to be stratigraphically low in the section and below Formation D. Second, the author observed the small outcrop of black, finely laminated phyllite lying below the chert of Formation C on the lower northeast slope of Long Ridge, just above the previously mentioned prominent exposure of Formation A, which is labeled Cambrian undifferentiated by Widmier. He agrees with Widmier that the phyllite has an attitude at least similar to the orientation of the chert. Combined with this fact the observation can be made that Cambrian units increase in extent eastward on the southside of North Fork. The phyllite is believed to be an integral part of Formation A; its lithologic variation a result of diagenetic, if not metamorphic processes.

Formation B

Formation B is a non-fossiliferous, light gray silicified limestone and well indurated quartz siltite with dolomitized nodules. It is found at only one outcrop south of the North Fork, in a small anticline (Figure 5A), along the Park Road, and only interruptedly immediately to the east. Its thickness is given by Widmier as several hundred feet, but only ten feet were observed.

Widmier explains the lack of Formation B further to the east (previously discussed under Formation A) as the result of plastic flowage off the anticlinal crest, which is seen in the small anticline in the quartz siltite and in the structure of later formations. But here the evidence seems to point to faulting which caused Formation B to be omitted (see geologic map, plate 1).

Formation C

Formation C is typically a massive dark blue to black, thinly bedded chert, of secondary, replacement origin. It is non-fossiliferous and no organic remains are found in thin section (figure 5B), in contrast to the radiolarian cherts found in the eugeosynclinal sequence to the west.

The chert is found in section above Formation B in scattered blocks along with blocks of Formation D, below the discontinuous ridge of chert on the lower east slope of Long Ridge. These blocks are not believed to be in place.

The ridge of Formation C, with about 30 feet exposed thickness of the unit, appears to be continuous under the alluvium of the canyon with the chert north of North Fork. The outcrop bends eastward, so as to further suggest the anticlinal structure previously mentioned. The prominent cliff of Formation C, south of the Park Road, illustrates the résistance of this formation to erosion. At this point it can also be seen that the chert is conformably overlain by Formation D.

Formation D

Formation D is the most extensive and variable of the formations within the area, and perhaps the most confusing. Widmier's columnar section (1960, p. 22) shows the thickness to be on the order of 3,000 feet but no estimate can be given here. It is composed of many varying lithologies, highly folded, faulted and otherwise deformed.

Generally, the formation is comprised of dense gray to black silty shale with calcisiltite interbedded in relatively equal amounts. The thin-bedded bluish calcisiltite alternate with thin-laminated buff argillites in several inch cycles (figure 6A). Formation D is a rhythmic fossiliferous sequence, bearing deformed trilobites, trilobite segments, Linguloid brachiopods, possible sponges and coral-like structures.

On the basis of a specimen of ? Olenoides, found to the north of North Fork, Formation D was considered to be Upper Cambrian (Kay, personal communication). The author and his assistant found three poorly preserved and incomplete trilobites, which seem to represent a species of Eurekia or similar late Cambrian trilobite, on Dry Canyon Ridge at an approximate elevation of 9,000 feet, SE 1/4, SW 1/4, Section 6, T.42 N., R.54 E., Wild Horse Quadrangle. Dr. Palmer of the U.S.G.S., has stated that the characteristics exhibited by these trilobites are known, only in rocks of Trempealeauan age. In Nevada this corresponds to the upper member of the Windfall formation at Eureka and near Cherry Creek. Mathias (1959) has described rocks similar to Formation D, in the Elk Mountains, also bearing Eurekia, which he records as Windfall formation. On this basis Formation D may be correlative with the Windfall formation. If this be the case Windfall equivalent rocks can be extended considerably farther to the north than previously.

Lithologically, Formation D is quite variable. Much of the differentiation is attributed to the degree of deformation and resultant metamorphism. The greatest variation in lithology can be observed on Dry Canyon Ridge. On the eastern slope buff, highly argillaceous shales are crenulated and otherwise deformed. Farther west on the ridge, many other lithologies can be recognized, allowing a complete survey of the characteristics of Formation D.

Irrespective of the nature of the contact, Formation D as a whole, is easily distinguished from formations above and below.

Two distinctive members have been mapped to illustrate the structural relationships. On the northeast slope of Long Ridge, a thinly bedded black chert and calcisiltite forms a discontinuous outcrop ridge. It forms a local overturned syncline near the base of Long Ridge, and trends southwestward up the slope for several thousand feet to end at the unconformity. The rather intensive folding has created many minute fissures which are filled with calcite, giving the member a distinctive textural aspect.

On Rim Canyon Ridge another member of Formation D, consisting of dense gray calcisiltite, trends transverse to the ridge in several complex folds and faulted blocks, then extends eastward down the slope and disappears into the hill amidst Formation D hillwash. Immediately to the west of the calcisiltite, poorly exposed (for the most part) sequences of a brown-weathering, black, fissile calcilutite, several feet thick, a two to three inch thick argillite, and a dense black, thinly bedded chert (figure 6B) which is in contact with the calcisiltite, are found.

Upper Paleozoic Formations

Formation E.

Formation E is perhaps the most distinctive formation of the area consisting of a ridge-forming, chert and quartz pebble conglomerate grading into quartz siltite and cross-bedded calcarenite. It is the basal unit of the Upper Paleozoic sequence and lies with angular unconformity on Formation D, on the crests of Rim Canyon Ridge, Dry Canyon Ridge and Long Ridge. The unconformity can also be observed on the northeastern slope of Long Ridge and southwestern slope of Rim Canyon Ridge; where the thickness of Formation E was taped as 116 feet. Widmier gives the thickness as 120 to 160 feet. In addition to the difficulty of finding a complete section the characteristically changing facies of the formation combined with the irregularity and deformation of the unconformity surface make an accurate measurement not significant.

Widmier divides Formation E into three members. The author has observed these members where described and recognizes the lithic variation but does not feel that such a refinement is practicable, in view of the gradation between them, or that it would be of much use.

The basal unit is quartzite and chert pebble conglomerate (figure 7A). The chert is bluish-gray to black, and some jade green chert pebbles were observed. The quartz pebbles vary from almost white to almost black. The clastics are angular to subrounded, with coarse sand and granules within the interstices, cemented with silica and carbonate.

The second unit is "salt and pepper" quartz siltites and arenites with interbedded chert nodules. The texture is quite distinctive along Beadles Creek and on the northern slope of Long Ridge. It has a gritty texture and, although well sorted has the appearance of a subgreywacke (figure 7B).

A fossiliferous calcarenite, ranging from grayish blue to black in color, comprises the third unit. It is thin to medium bedded with characteristic orange and white sand grains scattered throughout the calcarinite matrix. Locally present bands of crinoid columnals and ossicles are from two inches to two feet thick. Brachiopods and other fossils occur but are poorly preserved.

In addition to the localities mentioned, Formation E is found in two fault blocks, one on either side of Dry Canyon. Both blocks are bounded by the same fault, which also brought the exposure of Formation A into its position on the southeast slope of Dry Canyon Ridge, just north of Big Spring. These facts are consistent with the discussion of the structure that follows later.

Formation F

Formation F is present over much of the area as hill wash debris, but only rarely are good outcrops found. It consists of several thousand feet of black calcisiltites, dolomitic siltites, and brownish-red quartz siltites.

The formation was differentiated into four gradational members by Widmier: member 1, black, thin to medium-bedded quartzitic calcisiltite; member 2, brown and rust quartz siltites passing into interbedded medium to dark gray resistant dolomites quartz siltites and agillaceous siltites; member 3, red, rust and brown weathering quartz siltites with grey to black thinly bedded calcisiltites and calcarenite interbeds; and member 4, black, thinly bedded calcisiltites, passing into brown and rust quartz siltites with interbeds of black calcisiltites and thin layers of chert pebble conglomerate. These distinctions could not be substantiated by the author because of the highly variable nature of the rocks and their extensive deformation. However, Widmier's description gives a good impression of the variable nature of Formation F.

Formation F contains unidentifiable brachiopods, cephalopods and gastropods, as well as crinoid columals and calyxs and a few poorly preserved bryozoan fragments, Just below the crest of the nivation cirque of Rim Canyon, a good exposure of silty argillite with interbedded dolomite, contains algal remains and worm borings.

The friable nature of Formation F is a result of poor cementation. Except for the single sheltered exposure, Formation F is generally observed as hill wash and colluvium, which serve to mask structural relations.

Formation G

Formation G is of various lithologies which, are difficult to define stratigraphically. At the base, interbeds of black chert, several inches thick, lense throughout a light gray, medium bedded calcisiltite. Characteristically, this unit has a lattice-work of thin quartz and calcite veins. This unit is called "Black and White," and grades into a medium bedded quartz siltite with eight to ten feet of thin-bedded, black chert at the top; the total thickness is on the order of 200 feet thick which contrasts with Widmier's estimate of 460 feet. No fossils were found.

The calcisiltite forms a resistant generally north-south trending vertical ridge, at the base of the northwestern slope of Long Ridge, for a distance of about 800 feet, and then, forming a tight overturned syncline, trends west southwest across the northwestern base of Beadles Creek Ridge, in a discontinuous (faulted) overturned ridge. The outcrop appears irregularly; it roughly parallels the high angle border fault and is in part affected by it, the calcisiltite-chert being complexly folded and faulted.

The quartz siltite is locally exposed in outcrops along the trend of the interbedded "Black and White." The black, thinly bedded chert is exposed below the overturned western limb of the "Black and White," on the western bank of a gully which trends along the axis of the overturned syncline. The trend of the gully seems controlled by a fault, since formation H is displaced at this point and discontinuous. Across the alluvium to the north in Widmier's area, a fault has been mapped having similar trend to the one proposed here.

Formations H and I

In spite of the fact that Formations H and I, of Widmier's stratigraphic sequence, are not found in the Paleozoic south of the North Fork, they are discussed here for continuity, as they are included on the geologic map, and for their importance in age determination of the upper Paleozoic Formations. Both of the formations are fossiliferous and the faunules have been studied in some detail by Streeter and Klovan, of Columbia University. The brief description of the lithologies that follows is synthesized from Widmier.

"Formation H is a sequence of black calcisiltites, calcarenites, brown weathering, finely banded, reddish brown quartz siltites which split along smooth planes, and chertified limestones. Formation H is in fault contact with Formations G and I.

Formation I consists of light gray to black, brown weathering, thin to medium bedded calcisiltites, calcarenites, and dolomitic siltites with chert replacement lenses, passing into reddish brown weathering thin bedded siltites interbedded with black chert. Formation I is in high angle fault contact with the western facies. Brachiopods, particularly Productids and Rhynchonellids, are dominant fossils. Fragments of molluscs and bryozoans are also found, as well as some crinoid columnals."

An age range of upper Mississippian to lower Permian (Wolfcampian) has been assigned to Formations H and I on the basis of the fossils, in spite of difference in opinion as to identification of certain genera. The exact stratigraphic and structural relationships of Formation H and I are uncertain. However, from deductive considerations, it may be concluded that Formations E, F, and G are older, since Formation E rests with angular unconformity on Formation D, dated as Trempealeauan age, and Formation F and G are conformably successive. The Upper Paleozoic formation would then range from Ordovician to lower Permian. However, the earliest deformation in the miogeosynclinal belt occurred in the late Devonian (Nolan 1928, Kay 1952, Dott 1955), therefore, some of the folding and faulting in Formation D occurred in the late Devonian. According to Dott (1955), orogeny in northern Nevada culminated during Mississippian time and unrest continued intermittently during Pennsylvanian time. It is then reasonable to assume that Formation E is late Devonian through Pennsylvanian. But this does not limit further the age of higher Paleozoic formations.

It is assumed that the eugeosynclinal sequence was thrust over the miogeosyncline and then later eroded after juxtaposition to the eastern facies by high angle faulting. Since the western facies is Mississippian in part (Fagan, 1960) and thrusting is dated only as post Mississippian and pre-Miocene by Fagan, this is of little help in the narrowing of the age of the miogeosynclinal sequence. However, Roberts and Lehner (1955) state that near Carlin, Nevada, conglomerates and limestones of Pennsylvanian age rest unconformably upon rocks of both the eastern and western facies. This suggests that the thrusting began in or before Pennsylvanian time." Therefore, if the thrusting of the western facies had occurred during the Pennsylvanian, then it would be more likely that Formations H and I were Carboniferous in age, as Widmier, for one, states. This is not conclusive, however, since there probably was more than one time of major thrusting. No doubt, the age of thrusting varied from place to place, and more than one generation of thrusting existed in most areas.

STRUCTURAL GEOLOGY

General Statement

The Paleozoics of south lower North Fork are similar in structural complexity to those of other areas of the Basin and Range Province. Numerous features that characterize the Province such as thrust faults, high angle faults, complex folds -- some of which are overturned -- and unconformities are to be found in this limited area of miogeosynclinal rocks.

The autochthonous eastern facies rocks, of Cambrian and Carboniferous age, are in juxtaposition to allochthonous, Carboniferous western facies rocks, by high angle faulting about their periphery. The result is a "Trap-Door" like structure. Complex folds related to late Devonian orogeny and some associated with the major thrusting occur along with minor thrusting within the autochthone. Further complication of the structure was caused by high angle faulting, involving repetition of beds, and deformation of the unconformity surface.

High Angle Border Faults

The contact of the miogeosynclinal and eugeosynclinal terranes, trends across the base of the northwestern slope of Beadles Creek Ridge in a northeasterly and southwesterly direction. Its extension to the north runs through the campground beneath the alluvium into the area of Widmier. From the slope of Beadles Creek Ridge, the contact trends across Beadles Creek, is concealed by morainal deposits, and then cut off by a high angle fault, on the southern border of the area, which trends east-west, approximately.

The fault contact is well substantiated at several localities. On the west northwest slope of Beadles Creek Ridge, Formation G ridge ends abruptly; a drag block of Formation G with irregular orientation is suggestive of fault displacement. The spring in the southwest portion of the campground is a probable effect of the fault. More conclusive evidence is derived from the disappearance of Formations H and I and the occurrence of the eugeosynclinal sequence in contact with Formation G. The linearity of the eugeosynclinal-miogeosynclinal contact, in addition to the attitude of the overturned Formation G, evidences high angle faulting.

Though there is sufficient evidence for the recognition of a high angle fault at the contact of western and eastern facies, the amount of displacement is uncertain. It is believed that the eugeosynclinal sediments moved down relative to the miogeosynclinal sequence.

According to Fagan (1960), thrusting of the western facies over autochthonous carboniferous rocks can be seen in the field just above the north bank of the North Fork between the mouth of Beadles Creek and Water Canyon (Wildhorse

Quadrangle). This exposure combined with the extreme lithic contrast between the two sequences, reflecting different depositional environments, supports the hypothesis of major thrusting. High angle faulting, subsequent to this thrusting, resulted in the contact of allochthonous and autochthonous sequences. Furthermore the exposure of Formations E along Beadles Creek, conformable below Formation F, supports postulation of the relative displacement. The deformation of the Carboniferous rocks concomitant to major thrust faulting makes estimation of the amount of throw uncertain, but is probably measurable in thousands of feet. The occurrence of this exposure, additionally reveals tilting, whether by epeirorogenic or orogenic mechanisms, of the Carboniferous sequence; this is discussed later.

The light-colored, massive orthoquartzites, of the high peaks in the southwest corner of Wildhorse Quadrangle, are in fault contact with the miogeosynclinal rocks to the north. The previously mentioned east-west trending high angle fault forms the southern border of the area. These orthoquartzites were formerly considered to be autochthonous and probably Cambrian; however, Fagan (1960) interprets the quartzite to be in the same allochthonous sequence as the western facies. It can be shown structurally that the shallow water, miogeosynclinal facies lies below the quartzites.

The east-west trending high angle fault on the southern border of the area, has been traced from the western slope of the moraine along Beadles Creek, eastward across the

U-shaped valley and cirque, then through saddles on Beadles Creek Ridge into Peterson Creek Valley where it is concealed by alluvium and glacial debris, then along the north slope of Peterson Creek Ridge, to where it is cut off by the range front faults. At the locus of the fault in Beadles Creek Valley, the fault is split, in horsetail fashion (figure 8A). At the origin of the western lateral moraine along Beadles Creek the fault plane is observed, dipping to the south (figure 8B).

Along the prominent saddles on Beadles Creek Ridge (figure 9), shear zones and calcite and quartz mineralization are found. Faulting may account for a striking fault block of quartzite strongly isolated from the main body of massive orthoquartzite, which forms the backbone of the northern Independence Mountains.

Further, along the contact of the orthoquartzites and the eastern facies rocks, presence of the fault is shown by the abrupt change in lithologies. Frequently, the contact is masked by glacial debris, alluvium and talus.

The eastern limit of this Paleozoic miogeosynclinal sequence is marked more by physiographic features (figures 2 and 4) than by contrasting lithologics, brecciated terrane, and other evidences that characterized the previous border faults. The linearity along the front of the range is striking and suggestive of faulting, in addition to the scarp, now well eroded.

The range front faulting is accomplished by several faults, which will be discussed later, however, there is a principal fault which is evidenced by differing lithologies of the miogeosynclinal facies of the mountains and the orthoquartzites of the pediment levels. The fault trends along the margins of the two aforementioned geomorphic features from Peterson Creek Ridge, successively across the base of Dry Canyon and Long Ridges north northeastward. Brecciated quartzite is found locally to the east of the contact, which is frequently obscured by alluvium. However, on the east southeast slope of Long Ridge, the fault plane is visible and is dipping 70 degrees to the east. At the base of the northeast slope of Dry Canyon Ridge a highly brecciated and mylonitic zone is observed along the trend of the fault. Fagan (1960) has suggested that the range front fault may be continuous with a fault crossing the head of Fry Canyon of Widmier's area, thereby completing the borders of the triangular shaped area.

It is possible that the eastern high angle border fault has considerable strike-slip movement, though no positive evidence is found in the Paleozoic of south lower North Fork. However, if the fault, discussed by Fagan, trending across the head of Fry Canyon, is continuous with the range front fault, as it appears to be, strike slip movement is suggested by the displacement of the almost vertical sequence of Formation E, north of North Fork Creek near the canyon mouth.

In consideration of a multiple working hypothesis, in regard to the explanation of the structure of this triangular shaped area, it is possible that its formation is similar to that of the "Trap-Door" structure of Nelson and Church (1943) with Basin and Range faulting superimposed. According to Nelson and Church, a "Trap-Door" structure is "a block type of foreland structure, the essential feature of which is a sharply asymmetrical flexure usually broken on its steep flank by a high-angle fault. The flexure or fault or both generally outlihe two adjacent sides of the block and displacement is commonly greatest at the corner. The fault surface curves in under the block, and in more advanced stages actually becomes a thrust fault, indicating its ramp-like character. "Trap-Doors" are thus interpreted as resulting largely from horizontal stresses transmitted through the more competent crystalline complex below the sedimentary cover to pre-existing zones of weakness, where they break up toward or through to the surface to produce a fault having a 'sled-runner'-like profile." This would mean, that the western border fault would be a reverse fault, as it is thought to be (Fagan, 1960), and the eastern border fault would be a normal fault with right lateral strike-slip movement, as is here proposed. The horizontal compressive force or principle stress axis would be in an approximate east and west direction, the intermediate stress axis would be oriented in a north-south direction and the least stress axis would be vertically oriented. The dating of the formation of this structure can only be given as post-Mississippian and pre-Miocene.

Thrust Faults

There is only one thrust in the rocks of the south lower North Fork as was previously indicated in the stratigraphy section. This thrust trends northwest, and Formation A is in the thrust sheet, which is assumed to be an extension of the structure across the alluvium, north of the Park Road.

For this thesis, the thrusting in Widmier's area, is important for support of the "Trap-Door" structure. In the original description of that structure, it is stated that, "displacement is commonly greatest at the corner" (of the block). Therefore thrusting, such as is found in the Paleozoic north of the North Fork, would be expected. Additionally, Widmier states, that "the evidence supports east to west thrust movement as opposed to the typical thrusting along the Robert's Line." This is consistent with the proposed explanation of the overall structure of the area as a "Trap-Door" structure.

Cambrian-Carboniferous Unconformity

The unconformable position of Formation E, believed to be Carboniferous, above Cambrian Formation D, is seen on the crest of Long Ridge (figure 10) and elsewhere, notably, midway up the north east slope of Long Ridge. The sinuous trend of the contact of the unconformity suggests moderate deformation, after deposition.

As would be expected, the angle of contact of the unconformity varies from almost 0 degrees to approximately 65 degrees. At the contact of the unconformity on the crest of Long Ridge, Formation D is essentially flat lying, while Formation E dips fairly steeply to the west. This reflects tilting and other deformation of the Carboniferous rocks. Formation D has highly variable attitudes, indicating deformation during orogeny.

In addition to the angular nature of the contact, the chert and quartz pebble conglomerate of the overlying Formation E evidences the hiatus in deposition of sediments, and gives clues to the tectonism, environment, and source of the sediments. The cherts and quartzites indicate a western source. The few green chert pebbles in the conglomerate are quite similar lithically to cherts of the eugeosynclinal sequence to the west.

Folds

Folding is frequently seen in the mapped area, especially in the Cambrian rocks. The slightly-southwest-plunging anticline, near the base of the northeast slope of Long Ridge, is the largest of the folds. Though the flexure seen in Formation B, alohg the road cut, is relatively small, the considerable magnitude is realized by following the trace of Formation E. The axis of the anticline is normal to the direction of the principle stress axis, as expected, further substantiating the "Trap-Door" hypothesis.

Other folds, but of smaller scale, are the overturned synclines in Formation D, on the north east slope of Long Ridge and on Rim Canyon Ridge. These deformational features are indicated primarily by axial plane cleavage and drag folds. Formation D on Peterson Creek Ridge also, illustrates the highly deformed nature of the Cambrian sequence, in contrast to the general broad warping of the Carboniferous rocks, that have a general homoclinal dip to the west. Some minor folding is quite intense showing evidence of shear folding.

Formation G proposes one of the more perplexing problems of the area though it is stratigraphically higher than Formation F, it lies below Formation F on the northwest slope of Long Ridge, and dips either vertically or into the hill. On closer inspection, it is seen to be overturned. The overturning may be a result of horizontal compression concomitant with the major thrusting of the eugeosynclinal group over the miogeosynclinal sediments. "If the intensity of the compressive force diminishes downward, the uppermost layers moving more than the lower layers, a couple is superimposed upon the simple compression. This causes asymmetry and overturning of the folds (Billings, 1954)." However, it is much simpler to consider the overturning of Formation G as a drag phenomena along the adjacent reverse fault, exaggerated by ground creep. It would seem that this latter explanation is more plausible since there is relatively little complex folding in the other Carboniferous formations.

High Angle Faults

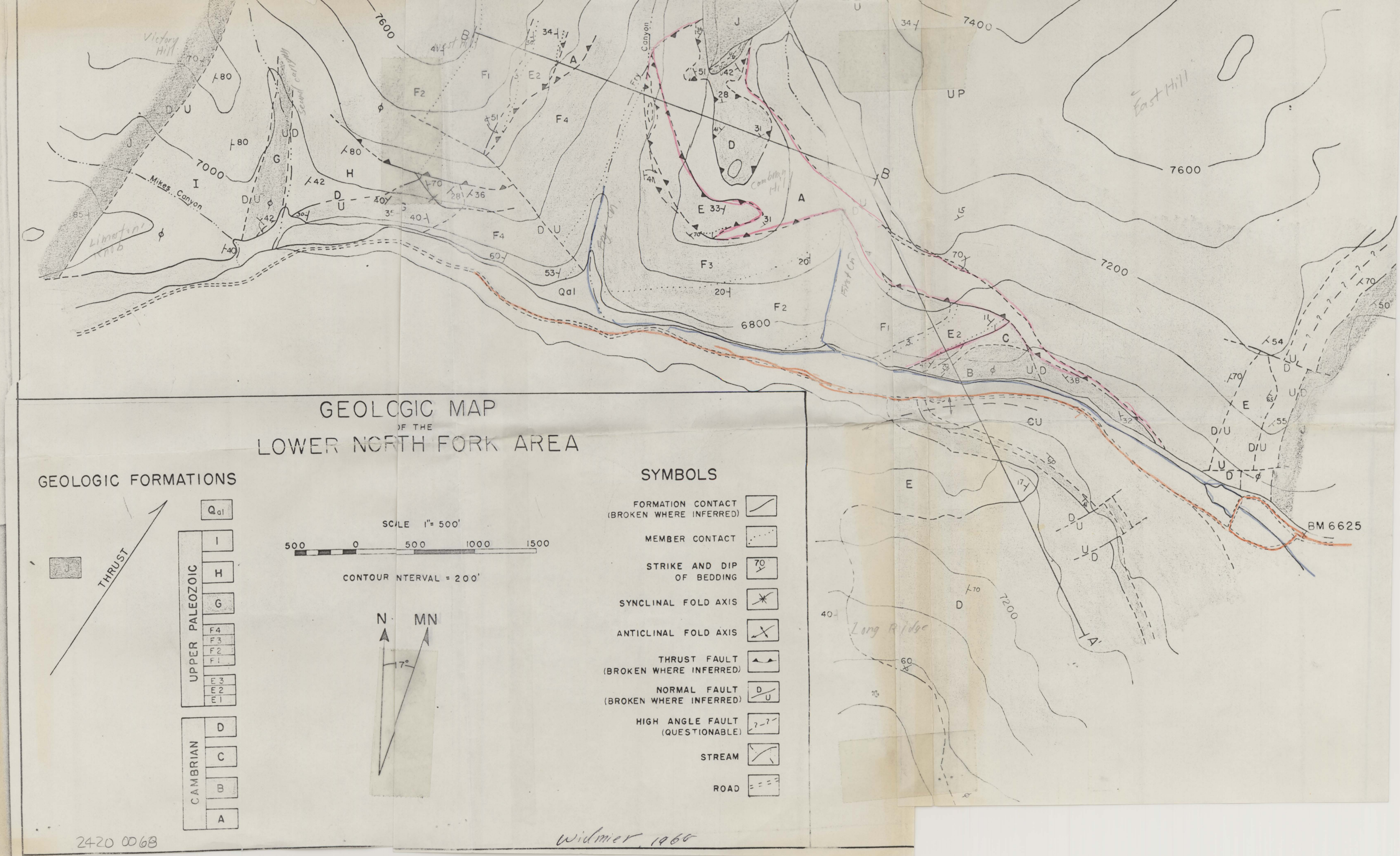
The range front fault is a composite of several faults. In addition to the principal high angle border fault discussed previously, there are about six other, north northeast trending, high angle faults superimposed upon the already complicated structure, which according to Osmond (1960) are the result of a shear couple. These faults characterize the area with its "en echelon series of ramp like segments," from which the name block-faulting is derived. Also there are several other northwest-trending high angle faults that seem to form a complimentary shear system with a southwest trending high angle fault, mostly concealed by alluvium and glacial debris, in the southwest corner of the area. These conjugate shears, indicate the maximum stress axis to be orientated approximately east-west, suggesting direction of thrusting. No doubt other faults exist within the area, but were not positively identified and therefore are not included here.

The second fault west of the principal range front fault is indicated in several ways. Prominent scarps are found on Rim Canyon Ridge, just west of Big Spring, on Dry Canyon Ridge and on Long Ridge almost along a straight line. This linearity vouches for the high angle of the fault and the occurrence of the spring is suggestive of a major fault.

Additionally the exposures of Formation A on the southeast slope of Dry Canyon Ridge to the west of the fault, and Formation E on the southern slope of Long Ridge to the east of the fault, indicate the relative movement. As is the case with all of the north-south trending, high angle faults, the eastern block has moved down with respect to the western block.

This faulting seems to be similar to the typical Toreva block faulting of slump structures. Osmond considers these faults to be antithetic, or faults that dip toward the master fault, but where displacement is of the gravity type, the other faults show remarkable linearity (figure 11) and have many features in common. Brecciation, shear zones (figure 12) and mineralization, such as iron oxides, calcite and aragonite are typical features marking the existence of faults. Lithologic contrasts and highly variable attitudes of the beds, along the fault traces give further proof of faulting. Repetition of Formations E and F (figure 12) on Long Ridge may also be attributed to faulting.

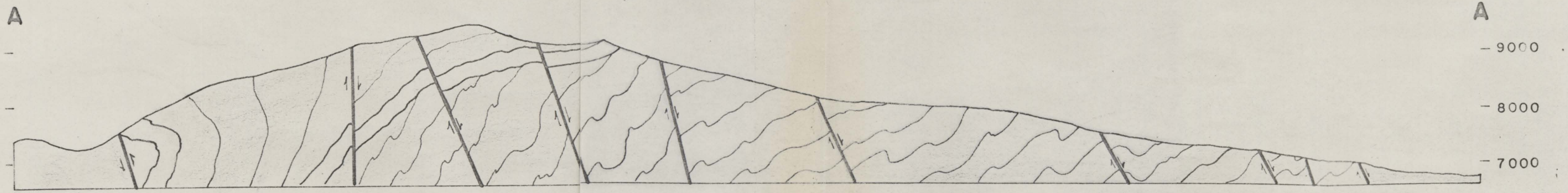
Along the north slope of Long Ridge, just below the crest, Formation F is in contact with Formation D. It is possible that a combination of north-south high angle faulting coincident with the fluctuating nature of the unconformity is responsible for this character. But reverse faulting concomitant with the border faulting, is considered the more reasonable explanation.

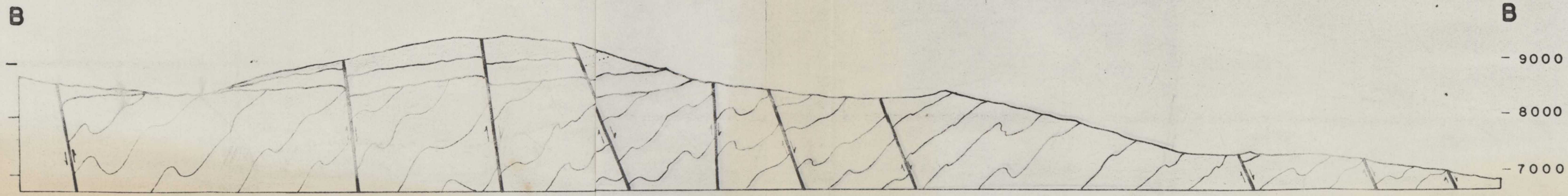


GEOLOGIC MAP
OF THE
LOWER NORTH FORK AREA
GEOLOGIC FORMATIONS
J
THRUST
Qal
UPPER PALEOZOIC
I
H
G
F4
F3
F2
F1
E3
E2
E1
CAMBRIAN
D
C
B
A
SCALE 1" = 500'
500 0 500 1000 1500
CONTOUR INTERVAL = 200'
N
MN
7°
SYMBOLS
FORMATION CONTACT (BROKEN WHERE INFERRED)
MEMBER CONTACT
STRIKE AND DIP OF BEDDING
SYNCLINAL FOLD AXIS
ANTICLINAL FOLD AXIS
THRUST FAULT (BROKEN WHERE INFERRED)
NORMAL FAULT (BROKEN WHERE INFERRED)
HIGH ANGLE FAULT (QUESTIONABLE)
STREAM
ROAD
Victory Hill
Mikes Canyon
Limestone Knob
Fry Canyon
Cambrian Hill
East Hill
Long Ridge
7600
7400
7200
7000
6800
BM 6625
2420 0068
Widmier, 1960

STRUCTURE SECTIONS

Hawkins





2420 0069