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PROPOSED CORRELATION OF AN ALLOCHTHONOUS QUARTZITE SEQUENCE IN THE ALBION MOUNTAINS, IDAHO, WITH PROTEROZOIC Z AND LOWER CAMBRIAN STRATA OF THE PILOT RANGE, UTAH AND NEVADA

by

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ABSTRACT

A thick sequence of quartzite and schist exposed on Mount Harrison in the Albion Mountains, Idaho, is described and tentatively correlated with the upper part of Proterozoic Z McCoy Creek Group and Proterozoic Z and Lower Cambrian Prospect Mountain Quartzite (restricted) in the Pilot Range, Utah and Nevada, on the basis of lithology, thickness, and sedimentary structures. Correlations with early Paleozoic or middle Proterozoic strata exposed in central Idaho are considered to be less probable.

Rapid thickness changes and locally thick conglomerates in Unit G of McCoy Creek Group (and its proposed correlatives in the Albion Mountains) indicate that depositional environments were variable locally. Environments were more uniform during the deposition of limy shaly and limestone in the top of Unit G and quartz sandstone in subsequent strata.

The strata on Mount Harrison identified as Proterozoic Z and Lower Cambrian in this study are part of an overturned, structurally complicated sequence of metasedimentary rocks that lie tectonically on overturned, metamorphosed Ordovician carbonate strata and possible metamorphosed Cambrian shale, suggesting that a typical miogeoclinal sequence (Proterozoic Z to Ordovician) was possibly once present near the Albion Mountains area. Elsewhere in the Albion Mountains and the adjoining Raft River and Grouse Creek Mountains, however, Ordovician carbonate rocks appear to stratigraphically overlie metamorphosed clastic rocks of uncertain age that are dissimilar to miogeoclinal rocks of the region. The section on Mount Harrison may be a relict of a more complete section which is tectonically thinned elsewhere in the metamorphic terrane, or may be a far-travelled allochthonous slice of miogeocline juxtaposed with non-miogeoclinal facies rocks of similar age.

INTRODUCTION

Proterozoic Z strata conformably underlie Cambrian strata throughout much of the Cordilleran miogeocline (Stewart and Poole, 1974). A Proterozoic Z sequence has been well documented near Huntsville in northern Utah and in the Pocatello area of southern Idaho (Crittenden and others, 1971); the similar McCoy Creek Group is exposed beneath Cambrian rocks in eastern Nevada (Misch and Hazzard, 1962; Woodward, 1963, 1965, 1967). In contrast, the metasedimentary rocks overlying Archean basement in the Albion, Raft River, and Grouse Creek Mountains of southern Idaho and northeastern Utah constitute an exceptionally thin sequence that is lithologically different from the typical miogeoclinal rocks exposed elsewhere in southern Idaho and northern Utah. It has been reported that the usual assemblage of thick Proterozoic Z strata is either missing in the Raft River, Grouse Creek and Albion Mountains or that pronounced facies changes make it unidentifiable (Compton and Todd, 1979; Crittenden, 1979; and references cited therein). As a result of recent mapping in the Pilot Range, Nevada and Utah (Fig. 1) and in the northern Albion Mountains (Miller, 1978, 1980), I consider that the upper McCoy Creek Group and overlying strata exposed in the Pilot Range correlate with lithologically similar strata in the northern Albion Mountains. Details of the correlation are given in this paper, along with some tectonic implications.

REGIONAL SETTING

The northeastern Great Basin (Fig. 1) is characterized by generally north-trending, fault-controlled ranges separated by basins that are filled with Cenozoic deposits across which correlation of some strata and structural elements is difficult. The Basin and Range structures are superposed on Tertiary and Mesozoic high-angle and low-angle faults of local and regional extent. Despite the resulting structural complexity, stratigraphic correlations of Paleozoic and younger strata have been carried confidently over much of the region. Structurally complex areas, many of them containing metamorphosed strata, still pose problems despite extensive study in recent years, partly because correlations with unmetamorphosed strata are difficult. The metamorphic terrane in the Albion, Raft River and Grouse Creek Mountains region (Fig. 1) contains anomalous strata of largely unknown age. Ranges east and west of this terrane expose only upper Paleozoic strata, and north of the terrane sedimentary rocks are covered by volcanic rocks of the Snake River Plain. South of the Albion-Raft River-Grouse Creek metamorphic terrane the Pilot Range contains a relatively well known and extensive Proterozoic Z and Paleozoic stratigraphic section that is moderately metamorphosed. It is therefore a logical area to look for units possibly correlative with highly metamorphosed and deformed strata in the adjacent metamorphic terrane.

The Albion-Raft River-Grouse Creek metamorphic terrane is characterized by stratigraphic attenuation resulting from low-angle faulting and plastic flow, but the work of Armstrong (1968), Compton (1972, 1975), Todd (1973, 1975, 1980), Compton and others (1977), Armstrong and others (1978), and Miller (1978, 1980) has established a surprising lateral consistency of a sequence of thin metasedimentary units over most of this terrane. This sequence, have termed the "Raft River sequence" from Compton's studies in the Raft River Mountains, includes six lower rock units of uncertain age (Compton and others, 1977; Compton and Todd, 1979; Crittenden, 1979), including the Elba Quartzite, schist of the Upper Narrows, quartzite of Yost, schist of Stevens Spring, quartzite of Clarks Basin, and schist of Mahogany Peaks, overlain by units of the Raft River sequence representing metamorphosed Ordovician (Pogonip Group, Eureka Quartzite and Fish Haven Dolomite) and Mississippian (Chainman-Diamond Peak Formations undifferentiated) strata. The Raft River sequence rests unconformably on gneiss and schist of Precambrian W age and is tectonically overlain by upper Paleozoic sedimentary rocks. Major low-angle faults are common within the Raft River sequence, contributing to the difficulty of assigning ages to the lower units. Southward in the Grouse Creek Mountains thin slices of metamorphosed Devonian strata appear within the sequence in their proper stratigraphic position (Miller and others, 1980).

Strata in a major area of the Albion Mountains differ from the relatively simple sequence of units in the remainder of the metamorphic terrane. Along the western side of the mountain range, including Middle Mountain, the western flank of Mount Harrison, and the northern continuation of the range west and north of the town of Albion (Fig. 2) is a terrane composed largely of metaquartzite, with minor schist and marble, and with variable amounts of intrusive gneissic granite. This terrane is here termed the "quartzite assemblage." It is of uncertain age and appears to be a high-level tectonic sheet that lies above all rocks except the sheet of Pennsylvanian strata in the northern part of the range; however, the relations are unclear in many exposures. Part of the quartzite assemblage is well-exposed on Mount

Harrison, where an overturned sequence of quartzite and schist was identified by Armstrong (1968, 1970); it is here termed the "Mount Harrison sequence." The Mount Harrison sequence underlies another part of the quartzite assemblage that lies along the western side of the Albion Mountains in the Mount Harrison area; this higher part of the assemblage is here termed the "sequence of Robinson Creek" (Fig. 3). Although the sequence of Robinson Creek is lithologically similar to the Mount Harrison sequence, it is in my interpretation separated from it by a low-angle fault and therefore is not definitely correlative. Armstrong (unpub. maps, 1977) considered the Mount Harrison sequence and the sequence of Robinson Creek to be partial equivalents. The Mount Harrison sequence is faulted over metamorphosed, overturned Paleozoic strata belonging to the upper part of the Raft River sequence. In view of the correlation of the Mount Harrison sequence with Cambrian and Precambrian rocks of the miogeocline proposed herein, the tectonic relations at the base and the top of the Mount Harrison sequence have important implications for the age of the lower part of the Raft River sequence because Armstrong (1968, 1970) and Compton and Todd (1979) have suggested that strata within the Raft River sequence differing drastically from the Mount Harrison sequence also may be of Cambrian age.

MOUNT HARRISON SEQUENCE

Several low-angle faults occur in the Raft River sequence on Mount Harrison but their existance and position are commonly obscured by subsequent metamorphism. Tectonic relations among the metasedimentary units within the sequence are therefore uncertain. On Mount Harrison metamorphosed Ordovician (?) strata of the upper part of the Raft River sequence are inverted (Miller, 1980), suggesting that a major recumbent fold is present within the Raft River sequence. Overlying the inverted Ordovician units of the Raft River sequence and separated from it by a low-angle fault zone containing broken, dark schist and graphitic phyllite, is a sequence of two quartzites with intervening schist that is overturned, based on cross beds (Armstrong, 1970; Miller, 1980). I consider this sequence, the Mount Harrison sequence, to be stratigraphically intact because all well-exposed contacts are conformable and because the quartzites are similar. Lenticular outcrop patterns of thin quartzites enclosed by schist may have either a tectonic or primary depositional origin. Armstrong (1977, unpub. maps) interpreted local elimination of one of these lenticular quartzites as due to low-angle faulting, while I consider the elimination to be a large-scale boudinage feature accentuating primary channel forms. The Mount Harrison sequence is structurally truncated by the overlying sequence of Robinson Creek (Fig. 3) that, on Mount Harrison, consists largely of quartzite and schist that is generally similar to rock types in the Mount Harrison sequence. Lesser amounts of clean to schistose calcite marble and rare dolomite marble are also present in the Robinson Creek.

Stratigraphic Description

The Mount Harrison sequence consists of three distinctive units: Dayley Creek Quartzite of Armstrong (1968), schist of Willow Creek, and Harrison Summit Quartzite of Armstrong (1968) (Fig. 3 and 4). Armstrong (1968) originally defined the two quartzites with an intervening unit named the Land Creek Formation, part of which is now included in the sequence of Robinson Creek that tectonically overlies the Mount Harrison sequence. Consequently, I have renamed his Land Creek Formation as the schist of Willow Creek and restricted its usage to avoid confusion. Armstrong subsequently discarded the Land Creek Formation (Armstrong, 1977, unpub. maps; 1980, written comm.) and placed the rocks originally included in that unit in the Harrison Summit Quartzite and Dayley Creek Quartzite. The various interpretations are indicated in Figure 5.

Dayley Creek Quartzite of Armstrong (1968)

This unit, named by Armstrong (1968), is best exposed along the north-trending ridge north of Mount Harrison, in sections 29 and 32, T13S, R24E, where it is entirely overturned. The base of the section is cut by a high-angle fault, below which is more schist and quartzite mapped by Armstrong (1977, unpub. maps) as belonging to the Dayley Creek. The section described here includes a basal portion of approximately 800-1200 m of well-bedded and cross-laminated micaceous quartzite that crops out north of the area shown on Figure 3. This portion is succeeded by approximately 1,435 m of similar cross-bedded quartzite with one schist subunit. Thicknesses were estimated from structure sections.

The lowest part of the section consists of about 1100-1500 m of gray-weathering, light gray to white, micaceous quartzite with thin interbeds of biotite and white-mica schist. The rocks are fully recrystallized with the exception of granule-sized and larger quartz clasts, and are generally medium to coarse grained. Bedding is pronounced, and ranges from thin to very thick, but is generally medium to thick. Cross-laminations occur in planar sets and are ubiquitous; they are generally tabular, wedge-shaped, or form gentle troughs, and they lie at a low angle to bedding. Granule-sized quartz grains are common on bottoms of troughs; however only one conglomerate bed, about 1 m thick, was observed.

The lowest quartzite is abruptly overlain by 50 m of mica schist. The schist is mainly composed of biotite, white mica, feldspar, and quartz, but also contains some garnet and large crystals of staurolite. It weathers brown to tan, and is tan on fresh surfaces.

Gradationally overlying the schist subunit is schistose quartzite that contains abundant biotite and white mica schist partings and scattered coarse and fine mica crystals. Quartz granule beds lie 10 m above the contact with the schist, but highly micaceous dark gray quartzite continues for approximately 100 m. The micaceous quartzite contains green, fuchsite(?) bearing horizons; it grades upward into quartzite similar to that which underlies the schist subunit.

Approximately 350 m above the schist subunit the mica-bearing, gray quartzite rapidly grades into clean, white, thin- to medium-bedded and cross-laminated quartzite. This white quartzite subunit, about 335 m thick, contains rare granule layers at the base of troughs and no schist partings. It is overlain by about 300 m of darker quartzite that contains about 5% biotite and white mica and some iron oxide minerals. It is similar to the lowest quartzite in most respects. The uppermost 50 m of Dayley Creek Quartzite grades into schistose quartzite with increase in mica content and decrease in bed thickness. Feldspar fragments are an important constituent in many beds near the top. Thin interbeds of tan garnet schist are common near the top of the unit, which is drawn at the base of the first schist bed thicker than 4 m.

Schist of Willow Creek

Armstrong (1968) defined the Land Creek Formation as a dominantly schistose unit that lies between two thick quartzites, the Dayley Creek and Harrison Summit Quartzites. He incorrectly considered schist, quartzite and marble exposed south of Mount Harrison to be correlative with the schist exposed north of the mountain (the sequence described in this paper), and therefore included a number of rock types in the Land Creek Formation that do not occur in the sequence described in this paper. Armstrong (1980, written comm.) has subsequently discarded the name Land Creek Formation and redefined the Dayley Creek and Harrison Summit Quartzites as shown in Figure 5. I am here informally naming the unit that lies between the two quartzites the schist of Willow Creek to avoid confusion with earlier terminology.

The schist of Willow Creek crops out between the essentially continuous quartzite beds of the Dayley Creek and Harrison Summit Quartzites of Armstrong (1968). Much of the unit is well exposed along the ridge north of Mount Harrison (Fig. 3) in section 32, T12S, R24E, but the uppermost member is best exposed in the upper reaches of Willow Creek (section 5, T13S, R24E), for which the unit is named. The unit is composed of five subunits of alternating schist and quartzite that are informally subdivided as members identified by numbers. The members are broadly lenticular, and some are locally missing. The entire unit is approximately 510 m thick as determined from structure sections (Fig. 4).

Schist I member is about 105 m thick and consists of garnet- and staurolite-bearing, tan, pelitic and quartzose schist and interbedded lenses of light-grey, coarse-grained to granular, micaceous quartzite. Schistose quartzite beds near the base are as much as 3 m thick and are coarse grained to conglomeratic. The top is placed at the sharp contact with thick bedded quartzite.

Quartzite I member is about 60 m of impure, thick bedded quartzite. The base is flaggy, micaceous and feldspathic, gray quartzite with grain size ranging from coarse sand to granules. The remainder of the member is heterogeneous, containing thin beds of brown, quartzose garnet schist, feldspathic gray quartzite, clean, white quartzite, and boulder conglomerate with ripup clasts of schist and boulders of quartzite and rare granite (Fig. 6). Near the top muscovite becomes increasingly common. The top of the member is drawn at the base of the first thick schist bed of the overlying member.

Schist II member is about 130 m thick and consists of tan to brown, homogeneous, garnetiferous and quartzose schist. A few thin beds of tan quartzite occur near the base. Staurolite is locally present in the schist. The top is drawn at the base of the first thick quartzite bed of the overlying member.

Quartzite II member is approximately 90 m thick and has interbedded contacts with the underlying and overlying schist members. Interbedded tan, quartzose schist and gray, coarse-grained to pebbly quartzite occur at the base. The central portion consists of gray, coarse-grained to pebbly (pebbles up to 5 cm diameter), micaceous, poorly bedded quartzite. Thin interbeds of calcareous schist occur in the upper part. The top is drawn at the top of the uppermost quartzite of the sequence.

Schist III member is about 125 m thick and consists of a lower pelitic schist, a middle zone of interlayered marble and schist, and an upper quartzose schist. The lower schist part is tan to brown, pelitic to quartzose schist, and is thinly bedded (1-8 cm) and laminated. Regular color alterations caused by varying quartz content give a banded appearance similar to a rhythmite. The middle zone is medium to dark gray and brown, very thinly interbedded calcite marble and pelitic schist (Fig. 6). The upper part, 10 to 30 m thick, consists of dark gray to dark brown, spotted calcareous schist, quartzose schist, and schistose quartzite. Quartz content increases progressively upward in the top 20 m. The top is drawn at the base of the first white, thick bedded quartzite of the Harrison Summit Quartzite.

Harrison Summit Quartzite of Armstrong (1968)

Armstrong (1968) named the Harrison Summit Quartzite from the peak it underlies. The entire unit is overturned (Armstrong, 1970). The best exposure of the upper part of the unit is in the cliffs west of Lake Cleveland, section 4, T13S, R24E, where the unit is estimated to be about 740 m thick. The stratigraphic top is poorly exposed in a low-angle fault zone about 3 km south of the summit region, and contact relations between the Harrison Summit and the stratigraphically lower schist of Willow Creek are best exposed in upper Willow Creek.

The Harrison Summit Quartzite is thick bedded and prominently cross-laminated throughout. The cross beds are generally tabular or wedge-shaped and form planar bedding units; festoons are uncommon. In general the Harrison Summit is white to light gray or creamy white, generally medium-grained with a few granule layers at the base of beds and rare conglomerate beds containing pebbles less than 2 cm diameter. Thin, 1-5 cm, dark brown schist interbeds commonly occur near the top, along with infrequent rip-up clasts of similar lithology. Feldspathic beds are uncommon. Large cubes of hematite occur locally. The top is not exposed near Lake Cleveland, and is poorly exposed south of Mount Harrison where it is juxtaposed structurally with underlying schist and phyllite by a low-angle fault.

Overturned rock units that lie structurally under the Mount Harrison Sequence

Underlying the faulted stuctural base of the Harrison Summit Quartzite is a fault-bounded zone of dark schist, graphitic phyllite and quartzite (black schist unit of Fig. 4) that locally is highly jumbled and broken. It contains lithologies similar to both the schist of Mahogany Peaks and the Chainman-Diamond Peak Formations undifferentiated (Miller, 1978, 1980). The rock-types in this unit are also generally similar to dark, graphitic phyllite and schist of the metamorphosed Cambrian Pioche Formation in the Pilot Range, although fossils collected by Armstrong (1968) from a distinctive conglomerate in this unit several km south of Mount Harrison indicate that part of the unit is post Middle Cambrian. Between the exposures of overturned Ordovician rocks and overturned Harrison Summit Quartzite the black schist unit contains none of the distinctive conglomerate, and therefore may represent metamorphosed Pioche Formation. The base of this unit is bounded by a low-angle fault, below which overturned Ordovician Pogonip Group units thought to represent the Garden City Formation and Kanosh Shale successively occur (Miller, 1980).

PILOT RANGE SEQUENCE

A moderately metamorphosed assemblage of Proterozoic Z and Cambrian strata occurs beneath a gently arched decollement in the Pilot Range. The metamorphosed strata include three major rock groups (Fig. 7): the Proterozoic Z McCoy Creek Group (Misch and Hazzard, 1962), Proterozoic Z and Cambrian Prospect Mountain Quartzite (restricted), and overlying phyllite and marble of probable Cambrian age. The exact age of the Prospect Mountain Quartzite is uncertain because fossils are lacking, but it is commonly assumed to contain rocks deposited in Proterozoic and Cambrian time because it correlates with strata in southern Nevada shown to be Proterozoic Z and Lower Cambrian on the basis of fossils (Stewart, 1974). Strata above the decollement range from Upper Cambrian to Permian and are unmetamorphosed (Blue, 1960; O'Neill, 1968; Miller, unpub. maps, 1980).

The Prospect Mountain Quartzite crops out near the southern and northern limits of a window in the decollement that exposes metamorphic rocks; between these exposures of the quartzite older rocks of the McCoy Creek Group occur. Two composite stratigraphic sections ranging from the upper McCoy Creek Group to Cambrian phyllite are here described, one from each end of the window. The southern area is near Pilot Peak in the southern Pilot Range; it contains covered areas and is in part low-angle faulted. Fortunately, the structure is relatively simple in many places near Pilot Peak so that a composite stratigraphic section can be constructed with confidence. The northern exposures of Prospect Mountain Quartzite and adjacent strata are near Patterson Pass and are complicated by locally complex low-angle faults, major, tight folds, and rapid facies changes. Consequently the composite section for that area can be treated with less confidence. Geologic maps and structure sections are included for the areas discussed in order to impart the general structural relations.

Pilot Peak Area

The area near Pilot Peak (Fig. 8) consists of a gently to steeply east-dipping sequence of Proterozoic Z and Cambrian strata. A major low-angle fault lies near the top of Prospect Mountain Quartzite or within metamorphosed Pioche Formation in most locations. Low-angle faults with separations of less than 400 m are mapped within Unit G of the McCoy Creek Group where marker beds are present. It is probable that the section described below contains one or more of those unrecognized faults in lithologically homogeneous parts of the section. In other parts of the range low-angle faults are also present near the base of Prospect Mountain Quartzite. An analagous fault in the Pilot Peak area cannot be ruled out, as exposures are meager. The quartzite units are broadly folded in general, and tight folds are commonly associated with low-angle faults. Schists in Unit G, particularly those not rich in quartz or calcite, are generally moderately to tightly folded. The rocks were metamorphosed to middle and upper greenschist facies, and retrogressed to chlorite zone.

Woodward's (1967) correlation of Pilot Peak units underlying Prospect Mountain Quartzite with McCoy Creek Group is followed in this paper. The stratigraphic section described by Woodward (1967) was measured in the same general area as that of this report; however, because his section included complex structure, covered areas, and areas of exceedingly poor exposure, I have re-measured the section in different locations. Section thicknesses were determined from structure sections because the deformation of the rocks renders any exact thickness of little value.

McCoy Creek Group, Units A(?), B(?), C, D, and E

In the Pilot Range heterogeneous quartzite overlain by pelitic and amphibole schist is provisionally assigned to Unit A, overlying marble is provisionally assigned to Unit B, tan metasiltstone is assigned to Unit C (70 m), massive pebbly and granular quartzite is assigned to Unit D (215 m), and brown quartzose schist and metasiltstone is assigned to Unit E (150 m). Units A(?) and B(?) are structurally juxtaposed with Unit F and cannot be correlated with certainty with the lower units of Misch and Hazzard's McCoy Creek Group in the Schell Creek Range. These units are not considered in the regional correlation described here and will not be described further.

McCoy Creek Group, Unit F

A 300 m thick quartzite was designated Unit F by Woodward (1967). Near Pilot Peak (section 4 of Fig. 8) Unit F overlies platy brown schists of Unit E with sharp contact. The lower portion of the quartzite is gray- to brown-weathering, light-gray to white on fresh surfaces, poorly-sorted, medium sand- to granule-sized quartzite. It is generally moderately to poorly bedded in the lower 40 m. The central part is uniformly cross-laminated with tabular, wedge and trough shapes common in sets that form generally medium to thick, planar beds. There is a general trend from high-angle, tabular cross-sets to festoons upward in the quartzite. Pebbles less than 2 cm in diameter commonly form layers in channels at the base of cross-sets; pebbles are well rounded and consist of white vein quartz and quartzite. Clasts in conglomerate beds are matrix-supported, and rare microcline crystals up to 2 cm in diameter occur with quartz pebbles. Feldspar is a minor constituent of most fine grained beds. Higher in the central section some parts are slightly micaceous and locally beds thicker than 1 m are present. The upper 80 m contains a few beds of dark mica schist, as much as 15 cm thick, and dark, fine grained quartzite beds 10 to 20 cm thick. The upper part is typically bedded less distinctly than the central portion, and cross-laminations are less pronounced. The top 30 m of the unit varies laterally, and contains broad channels filled with pebbles. In a few locations the top 20 m consists of thick beds of micaceous quartzite with thin interbeds of dark-gray slate and slaty quartzite. Typically a conglomeratic subunit up to 30 m thick is present at the top. It is massive to very thickly bedded, matrix supported conglomerate that is poorly sorted. Clasts are 1 to 6 cm in diameter and dominantly consist of white vein quartz; at one locality red jasper or chert and purple quartzite clasts were noted. In most areas rip-up wedges of phyllite also are common (Fig. 9). The top of Unit F is drawn at the base of the first thick phyllite.

McCoy Creek Group, Unit G.

Unit G is approximately 480 m thick as determined from section 1 (Fig. 8). It can be divided into three general subunits: a lower quartzose phyllite, a middle interbedded phyllite and calcite marble zone, and an upper zone consisting of phyllite, quartzose phyllite and phyllitic quartzite.

The basal part is typically brown, laminated, quartzose phyllite that contains lenses or interbeds of brown conglomerate similar to that in the top of Unit F; and slate gray, micaceous metasiltstone that is in part rhythmically bedded and contains interbeds of phyllite, quartzose phyllite, quartzite, and conglomerate. Amphibole schist is present locally. In exposures of Unit G near section 1 of Figure 8, as many as three 10 to 20 m thick conglomerate layers are present in a zone about 80 m from the base of the unit. The conglomerate outcrops over 4 km along strike. It is poorly sorted, medium-sand sized to pebbly, and white. The matrix consists of biotite, feldspar, white mica, and quartz; the clasts are generally quartzite, but rounded and wedge-shaped rip-up clasts of phyllite are common. Above the conglomerate are light- to medium-gray, fine- grained quartzites separated by 10-15 m of green or grey slate and phyllite containing quartzose and calcareous pods and stringers that may represent lenticular or flaser bedding. Several km north of the Pilot Peak area interbedded conglomerate and phyllite compose the entire lower 100 m of Unit G; the lower portion there is designated the conglomerate member.

The middle zone, about 60 m thick, is characterized by interbedded calcite marble, calcareous phyllite, and phyllite or metasiltstone in layers 1-7 cm thick (Fig. 9). The marble is white, tan, dark-gray, or blue-gray, and slightly micaceous. Intervening beds are dark-gray, green or brown metasiltstone and phyllite, and brown, gray or tan calcareous phyllite and micaceous marble. This central portion of Unit G weathers more resistantly than the remainder of the unit and generally stands out on the gentle slopes formed by Unit G.

Overlying the middle zone is about 200 m of medium-gray, thin-bedded, fine-grained quartzite and metasiltstone containing biotite, feldspar and quartz. It grades upward to thin- and medium-bedded, medium-gray, fine- to medium-grained quartzite that weathers brown. The thin bedding and color variations between beds gradually disappear upward as the dominant lithology becomes uniformly medium-bedded, gray, faintly cross-bedded quartzite. This quartzite changes abruptly to light-gray, thick-bedded and prominently cross-laminated, coarse-grained quartzite of the Prospect Mountain Quartzite.

Prospect Mountain Quartzite (restricted)

Approximately 955 m of Prospect Mountain Quartzite was determined from section 3 (Fig. 8). The unit is prominantly bedded and cross-laminated, and remarkably homogeneous.The basal 50 m of Prospect Mountain Quartzite is brown or gray, micaceous (5 to 10%) quartzite and interbedded quartzose phyllite that lies in sharp contact with fine-grained, thin- or medium-bedded quartzite of McCoy Creek Group, Unit G. Other exposures of the basal part contain light-gray, clean quartzite or conglomeratic quartzite. In the measured section the interval 50 to 200 m above the base contains rare medium-thick interbeds of dark brown quartzite within the typically light-gray or white, coarse, poorly sorted, thick-bedded and cross-laminated quartzite. The overlying interval is all thick-bedded and cross-laminated, white to light-gray quartzite. Grain size ranges from medium sand to pebble (2 cm diameter), but is generally coarse sand sized. Pebbly and granule-rich beds are not common but some rare distinctive units form conglomeratic intervals several meters thick that are feldspathic. Generally the granules occur on bottoms of cross sets and the base of graded beds. Cross sets are commonly tabular or wedge-shaped, but festoons are noted in several locations. Quartzite ranges from clean in about 40% of the section to slightly or moderately micaceous in the balance of the section; feldspar is not abundant except in rare beds and metamorphic hornblende is rare. The uppermost 70 to 80 m of the unit commonly contains white mica on parting surfaces, 1 to 10 cm thick beds of metagraywacke or biotite-white mica-feldspar-quartz schist, and rare medium- to thick-beds of dark, rusty-brown, iron-rich, micaceous quartzite interlayered within the generally light-gray, thick-bedded quartzite. The top 10 m of the Prospect Mountain consists of white, thick-bedded quartzite with medium-thick interbeds of dark-brown to blue-gray quartzite that is overlain by dark- and medium-gray, medium-bedded, cross-laminated, micaceous quartzite near the sharp contact with the overlying metamorphosed Pioche Formation.

Metamorphosed Cambrian(?) Rocks

The metamorphosed Pioche Formation of Hintze and Robison (1975) in the Pilot Peak area is composed of two members; the lower is dark brown, quartzose, graphitic to pelitic, phyllite or schist. It appears to grade into overlying brown, micaceous quartzite and calcareous quartzite; brown schistose, hornblende-bearing, quartz-rich marble; and tan pelitic schist assigned to the upper member. Overlying this unit is clean white marble and schistose marble of Cambrian(?) Unit 2. The unit overlying the Pioche Formation is tentatively assigned to the Middle Cambrian on the basis of lithology and stratigraphic position.

Patterson Pass Area

Immediately south of Patterson Pass (Fig. 7) the Prospect Mountain Quartzite (restricted) is folded into an overturned, southeast vergent major fold with a northeast axis. Low-angle faults that eliminate stratigraphic section are located near the upper and lower boundaries of the quartzite and are folded along with the quartzite and adjacent units (Fig. 10). Underlying the Prospect Mountain Quartzite on the southern limb of the fold is a thick sequence of phyllite and conglomeratic quartzite that correlates with the conglomerate member of Unit G. The overlying phyllite of Unit G is generally similar to Unit G of the Pilot Peak area. On the northern limb of the fold, the conglomerate member lies under a thick section of Unit G but it is highly folded and faulted and therefore difficult to compare with southern exposures. Overlying the Prospect Mountain Quartzite is metamorphosed Pioche Formation, which is locally truncated by a low-angle fault, and an overlying sequence of slightly recrystallized, laminated limestone that probably is Middle Cambrian. These McCoy Creek Group units and Prospect Mountain Quartzite (restricted) are described in the following paragraphs. Thicknesses were determined from structure sections shown in Figure 10.

McCoy Creek Group Unit F

An approximate thickness of 430 m is indicated for this unit where measured on section 1 (Fig. 10). Unit F is similar in all respects to exposures in the Pilot Peak area. The top is marked by a conglomerate zone about 20 m thick containing rip-up clasts of phyllite, boulders of quartzite, and, locally, chert clasts. Interbeds of dark phyllite similar to that in overlying Unit G are common as well. The top is placed at the top of the uppermost thick conglomerate bed and is generally marked by a pronounced break in slope from the cliffy exposures of Unit F to moderate slopes of Unit G.

McCoy Creek Group Unit G.

The unit is divided into the conglomerate member and the upper member. The conglomerate member is further divided into four units on the basis of lithology. It is well exposed on the southern limb of the fold (section 2, Fig. 10), where the sequence is phyllite-conglomerate-phyllite-conglomerate and is about 595 m thick. The upper conglomerate is folded and truncated by a low-angle fault, and it is not clear whether it is in stratigraphic order or represents recumbently folded conglomerate of the middle conglomerate unit. The northern limb of the fold contains a thick pile of massive conglomerate with interbedded phyllite that in part is recumbently folded. I have been unable to correlate the exposures to the section on the southern limb due to structural complexities, but it appears that the conglomerate member is much more conglomeratic in the northern exposures.

The lowest unit, about 400 m thick, is dominantly dark quartzose phyllite and interbedded coarse quartzite and conglomerate. About 12 m of blue-gray, silvery weathering, schist containing 20-30% magnetite is present at the base. It is succeeded by interbedded zones of phyllite and quartzite 10 to 25 m thick. Phyllite-rich zones are dark-brown, dark-green, and dark-gray weathering; brown, green and gray; phyllitic, slaty or fissile rocks that are thin-bedded to laminated. Medium-grained, micaceous quartzite interbeds are common. Quartzite-rich zones are dark-brown and gray-brown weathering, brown to gray and light-gray strata that are chiefly medium-grained to conglomeratic, micaceous quartzite. Interbeds of dark slate and metasiltstone are common. Coarser beds in the quartzite are generally light-gray weathering. Common constituents of the conglomerate clasts and granule-sized grains are white vein quartz, dark and light quartzite, feldspar cleavage fragments that constitute as much as 20% of the clasts in some beds, and plates of phyllite forming as much as 30% of clasts in some beds. Quartzite layers are indistinctly bedded and rarely cross-laminated. Near the top of the unit blue-gray slates weather white and contain a small amount of calcite.

The second unit is mostly light-gray, coarse-grained to conglomeratic quartzite about 145 m thick. The base is marked by a sharp contact between light-gray quartzite and the underlying fissile, greenish slates. The lower 40 m or so is medium- to thick-bedded, cross-laminated with tabular and wedge sets, light-gray- medium-gray- and brown-weathering, micaceous quartzite. Pebbles occur in thin layers at the base of beds and as sparse, randomly distributed clasts in the finer grained portions. The quartzites are generally coarse, poorly sorted, and impure. The upper 105 m or so is massive to very poorly bedded polymict conglomerate with rare pebble-poor zones that contain as much as 20% feldspar. Quartzites range from light- to dark-gray and rarely are black; mica and feldspar are common matrix constituents. Clasts range considerably in size, shape, roundness and color. Most clasts are quartzite, but plates and rounded cobbles of phyllite are common above rare phyllite interbeds in the conglomerate.

The lower contact of the third unit of the conglomerate consists of phyllite interbedded with the conglomerate of the second unit. Most of the third unit is rhythmically bedded phyllite and metasiltstone, and it is about 50 m thick. Dark brown colors and gentle slopes serve to distinguish this member from the underlying, cliffy, white and gray conglomerate. It is overlain by 10-20 m of dark conglomerate, here assigned to unit four, that is similar to quartzite conglomerate in the second unit. Where the upper member of Unit G overlies the conglomerate member the structure is complex and the contact is probably a low-angle fault. The conglomerate member is poorly exposed in most areas on the northern limb of the fold (Fig. 10). Most exposures are of poorly bedded conglomerate similar to the second unit. Lesser dark phyllite is exposed in patches, but as yet the structure and stratigraphy has not been unraveled in that area.

Neither the base nor the top of the upper member of Unit G is definitely exposed in the Patterson Pass area. It is probable that the base is dark phyllite overlying the conglomerate of the top of the conglomerate member in the northern fold limb. At the northern border of the area shown in Figure 10 the upper member is continuously exposed from a fault(?) contact with underlying conglomerate to a point about 20 m below the base of Prospect Mountain Quartzite (restricted). The complex structure in that area consists of several low-angle faults and tight folds, so the measured thickness is of unknown value and the lithologic sequence could be seriously distorted. The sequence does conform well with the section of Unit G in the Pilot Peak area, both in thickness and lithology, so I consider this section to be a good representation of the upper member. The estimated thickness of the upper member is 525 m.

The lower portion of the upper member of Unit G is dark phyllite and metasiltstone with one or two lenses of coarse quartzite. It is possible, however, that these lenses are fault slices of neighboring units. The phyllite grades upward into medium- to thickly-interbedded marble and clastic rocks. The interbeds of clastic rocks are metasiltstone and dark, fine-grained quartzite. Upward the calcareous part of the section grades rapidly into dark, medium-bedded, cross-laminated, fine-grained quartzite with 1-10 cm thick interbeds of calcareous phyllite. Micaceous, thin- to medium-bedded, faintly cross-laminated quartzite continues to a point near the contact with Prospect Mountain Quartzite (restricted), where slopewash obscures the rocks. In general, the upper member is similar to Unit G of the Pilot Peak area above the zone of conglomerate (110 m from the base), with the exception that quartz is more common in much of the Patterson Pass section.

<u>Prospect Mountain Quartzite (restricted)</u>.

This formation is 700 m thick on the north limb of the syncline and 865 m thick on the south limb. In both areas a low-angle fault cuts out the top of the unit, and on the south limb a fault locally cuts out the base as well. Therefore, the thicknesses are minimum. The quartzite is folded on a small scale in a few places, but generally it is unfolded except on a scale of several km as a thick slab sandwiched between the overlying and underlying phyllitic units.

The lithology, sedimentary structures, and thickness of the Prospect Mountain in the Patterson Pass area are generally similar to equivalent exposures in the Pilot Peak area. Differences are apparent near the base and the top. Basal exposures include the dark, mica-rich quartzite and light gray, pure quartzite similar to rocks exposed near Pilot Peak, and in addition rare granule layers and some feldspathic beds containing 20 to 30% feldspar fragments are locally present. The top of the unit typically contains dark- to medium-gray or blue-gray quartzite that is locally conglomeratic. The coloring appears to be caused by iron oxides, as the mica content is generally low. Small, rounded shale pebbles are rare constituents in the conglomerate. Locally, the conglomerate dominates the top part of the section. In these areas it is as much as 4 m thick, contains thin interbeds of phyllite, and is typified by heterogeneous coarse clasts that include phyllite rip-up wedges.

Metamorphosed Cambrian(?) Rocks

The metamorphosed Pioche Formation is dark-gray graphitic and micaceous phyllite and slate that is about 295 m thick in the thickest exposure, which is in the hinge of the large syncline. In the upper half of the unit phyllite is interbedded with clean and micaceous limestone marble and calcareous quartzite. Because the unit contains a mix of rock types, I follow Hintze and Robison (1975) in designating it as the Pioche Formation rather than the Pioche Shale. This is succeeded by micaceous, thin-bedded to laminated marble that is designated as Cambrian(?) Unit 1a (Fig. 10). It is overlain by medium to thick bedded, clean marble with silty laminae that is designated Cambrian(?) Unit 1b. The Cambrian(?) marbles correlate in a general way with Cambrian(?) Unit 2 in the Pilot Peak area (Fig. 8).

CORRELATION OF ALBION MOUNTAINS AND PILOT RANGE SEQUENCES

Correlation of the rock sequences in the Pilot Range and Albion Mountains is difficult because of the metamorphism and deformation present in both areas. Extensive recrystallization in nearly all of the rocks described produced changes in apparent grain size, except for granules and pebbles, changes in primary clay mineralogy, and partial or complete elimination of fine sedimentary structures, fossils, and trace fossils such as worm burrows and tracks. In general quartzites are better preserved than argillaceous rocks. Complex folds and numerous low-angle faults also introduce many uncertainties in thickness and continuity in the measured sections. For example, Armstrong (1980, written comm.) has interpreted the section he observed on Mount Harrison to be interrupted by a low-angle fault, whereas I consider the sequence to be intact.

I consider the following criteria to be most significant for purposes of correlating metamorphosed strata: 1, stratigraphic sequence; 2, general lithology and thickness; and 3, distinctive rock types and sedimentary structures. These are discussed below.

1. Stratigraphic Position

In the Pilot Range the sequence of quartzite and phyllite described here underlies marble and phyllite that are similar to unmetamorphosed Cambrian strata elsewhere, indicating that the sequences exposed in the Pilot Peak and Patterson Pass areas are equivalent. Low-angle faults within both sequences generally truncate less than 200 m of section, and therefore are considered to be relatively unimportant in considering the equivalence of the two sequences. This is supported by other correlation criteria summarized below.

In the Albion Mountains, however, the sequence of strata in question is bounded by major faults, with the result that its position in the stratigraphic sequence is difficult or impossible to determine.

2. General Lithology and Thickness

In the Pilot Range the Prospect Mountain Quartzite is an easily distinguished unit because it is much thicker than other quartzites, homogeneous, and pervasively thick-bedded and cross-laminated. McCoy Creek Group Unit G is readily identified by its calcareous interbeds and the moderately to prominently conglomeratic lower member. Unit F is characterized by medium to thick bedding and prominent cross-lamination, which contrasts with underlying more massive quartzite of Unit D. It differs from Prospect Mountain in being much thinner and being less well-bedded near the base and top. These general lithologic characteristics allow the units to be correlated with confidence throughout the Pilot Range (Fig. 11).

The Mount Harrison sequence contains a distinctive thick-bedded, prominently cross-laminated, homogeneous quartzite that is 740 m thick, underlain by a unit with calcareous beds near the top and much conglomerate and quartzite in the middle and lower part, which in turn is underlain by more than 1400 m of quartzite that is characterized by pervasive cross-laminations and 5 to 10% mica. The sequence is therefore similar to the Pilot Range sequence on the basis of general features except that the lower quartzite is much thicker and more micaceous in the Albion Mountains (Fig. 11).

Strata of the Cordilleran miogeocline other than those in the upper Precambrian and lower Paleozoic cannot be correlated with the Mount Harrison sequence because the Paleozoic section is dominated by abundant carbonate, and the Precambrian strata, other than those close to the Precambrian-Phanerozoic boundary, do not contain any thick, cross-laminated quartzite units.

3. Distinctive Rock types and Sedimentary Structures

Thinly interbedded calcareous marble and dark phyllite is a distinctive feature of McCoy Creek Group Unit G in the Pilot Range and the schist of Willow Creek in the Albion Mountains. This rock-type is strikingly similar in the two ranges despite the metamorphism and deformation of the rocks (compare Figs. 6 and 9). In the Cordilleran miogeocline other interbedded phyllite and marble sequences, or their shale and limestone protoliths, are present in the Pioche Formation and McCoy Creek Group Unit A (Misch and Hazzard, 1962). In both of these intervals, however, the limestone units are thicker bedded, and quartzite or calcareous quartzite is a common associate. Therefore the phyllite and marble on Mount Harrison most probably correlate with Unit G of the McCoy Creek Group.

Laminated limestone, silty limestone, and siltstone were noted as distinctive characteristics of the equivalent of McCoy Creek Group Unit G, the Osceola Argillite, in the Snake Range of east-central Nevada by Stewart (1974). The Rainstorm Member of the Johnnie Formation in the Death Valley area contains the same distinctive laminated limestone, leading Stewart (1974) to correlate the Rainstorm with the Osceola Argillite and Unit G. Stewart (1974) also described lenticular quartzite and conglomerate in Unit G and the Rainstorm; these rock-types are similar to conglomerate channel-fills(?) in Unit G in the Pilot Range. The presence of these distinctive rock-types in correlative units over such a wide area supports the correlation of Unit G with the schist of Willow Creek proposed herein.

Local coarse conglomerates that contain phyllite rip-up wedges are common at several stratigraphic horizons in the sequences in both ranges. Such conglomerates are not present elsewhere in the Precambrian and Paleozoic section in the Pilot Range, and, to my knowledge, have been recognized only in the McCoy Creek Group and equivalent strata in other ranges in the northeastern Great Basin such as in the Promontory Range, (M. D. Crittenden, 1979, pers. commun.), in the Deep Creek Range, (Woodward, 1965), and in the Sheeprock Mountains (Blick, 1979).

Other possible correlations of the Mount Harrison sequence

Armstrong (1968) proposed that the Mount Harrison sequence and structurally overlying rocks of the quartzite assemblage correlate with Middle Paleozoic Kinnikinic Quartzite exposed in central Idaho. The Kinnikinic Quartzite was named by Ross (1934) from exposures of quartzite and lesser carbonate in the Bayhorse region of central Idaho and has since been redefined by Hobbs and others (1968) to include only the clean quartzite at the top Ross's Kinnikinic. Two distinct sections were described by Hobbs and others (1968). The first consists of Kinnikinic Quartzite (restricted) underlain by massive and sandy dolomite, which overlies thick, impure, heterogeneous quartzite; it is probably entirely Ordovician in age. The second section underlies Middle Cambrian shale and is composed of quartzite with pebble, shale, siltstone, and feldspar-bearing beds; these are underlain by silty and shaly dolomite and limestone, and siltstone; which in turn is underlain by thick-bedded, cross-laminated, locally dolomitic, shaly and silty quartzite. Although some of these strata resemble some of the strata on Mount Harrison, the sequences do not match. In particular, the central Idaho calcareous strata contain only a small amount of clastic material, while the schist of Willow Creek contains minor carbonate within a thick pelitic and clastic unit.

The Pioneer Mountains of central Idaho (Fig. 1) contain a lower, metamorphosed sequence of quartzite, schist and banded calc-silicate rock that was assigned to the Hyndman and East Fork Formations by Dover (1969). Members G, F, and E of the East Fork Formation are now recognized by Dover (personal commun., 1980) as metamorphosed Ordovician strata correlative with those described by Hobbs and others (1968). The underlying Hyndman Formation consists of thick-bedded, cross-laminated, locally pebbly quartzite (Member D), distinctively banded, green calc-silicate rock (Member C), feldspathic and pebbly quartzite (Member B), and pelitic schist (Member A). The calc-silicate rock (Member C) is distinguished from schist of Willow Creek on Mount Harrison by a distinctive uniform banding throughout the entire unit and a lack of quartzite. The East Fork Formation and Mount Harrison sequence therefore are probably not correlative.

Conclusion

The rock-types, thickness, and sedimentary structures of the Mount Harrison sequence are similar to rocks of the Proterozoic Z McCoy Creek Group and Proterozoic and Cambrian Prospect Mountain Quartzite (restricted) exposed in the Pilot Range. Distinctive strata such as thinly interbedded phyllite and marble, and coarse conglomerate containing rip-up wedges of phyllite occur in both sequences. I conclude that the Mount Harrison sequence probably correlates with Proterozoic Z and Lower Cambrian rocks in the Pilot Range. In view of uncertainties caused by structural complexities in both mountain ranges the correlation must remain tentative.

DISCUSSION

Proterozoic Z and Lower Cambrian Depositional Setting

Facies changes within the McCoy Creek Group in the Pilot Range and tentatively correlative rocks in the Albion Mountains reveal some of the characteristics of the Proterozoic Z depositional site of the Cordilleran miogeocline. Our understanding of the paleogeography of the basin is poor due to structural complexities, particularly thrust faulting, in the region; therefore, construction of palinspastic maps must await further tectonic reconstructions of the region. Correlation of the McCoy Creek Group with sequences in a similar stratigraphic position further east in Utah and southeastern Idaho is not yet established in detail and therefore discussion of the Proterozoic Z depositional basin is restricted to exposures of the McCoy Creek Group.

Assuming that the present locations of the McCoy Creek Group and the Prospect Mountain Quartzite in the Pilot Range approximately represent their original spatial relations, the following northward facies changes are apparent: a) Unit F thickens but the rock type and sedimentary structures remain essentially the same, and b) Unit G thickens dramatically with the introduction of coarse clastic and pelitic sediments near the base. The upper calcareous part of Unit G and the Prospect Mountain Quartzite are virtually unchanged northward.

On a regional scale, the upper units of the McCoy Creek Group change moderately in thickness from the Schell Creek Range (Misch and Hazzard, 1962) to the Deep Creek Range (Woodward, 1965), the Pilot Range, and the Albion Mountains (this paper). The upper part of Unit G contains laminated limestone in the Snake Range (Stewart, 1974), rare calcite or dolomite in the Deep Creek Range (Woodward, 1965, p. 316), no carbonate in the Egan Range, and relatively abundant calcareous rocks in the Pilot Range and possibly correlative strata of the Albion Mountains.

Unit H of the McCoy Creek Group, as defined by Misch and Hazzard (1962) is clean, white, well-bedded and cross-laminated quartzite that lies under the Prospect Mountain Quartzite in the Schell Creek Range. Woodward (1965, 1967) considered Unit H to be missing in the Pilot Range and to be thinned in the Deep Creek Range of Utah, and inferred that a regional disconformity is present at the base of Prospect Mountain Quartzite. It is probable that Unit H cannot be distinguished from the Prospect Mountain Quartzite as defined by Misch and Hazzard (1962) and Woodward (1967) due to northward facies changes. Unit H in the type area is difficult to distinguish from the Prospect Mountain Quartzite, and I therefore follow Stewart (1974) and include Unit H in the lower part of the Prospect Mountain Quartzite.

Pervasive cross-lamination in the well-sorted Unit F quartzite indicates that the rocks were probably deposited in a shallow sea with strong currents. The general change from tabular to festoon cross-sets and then to conglomerate upward in Unit F is suggestive of regressive conditions. The local conglomerates in Unit F and moderate thickness changes in the unit may result from variations in depth of deposition. Lenses of conglomerate in Unit G are most reasonably interpreted as channel fillings. Cobbles and shale rip-ups in the lenses suggest that deposition occurred after local erosion by a high velocity flow or current. Rapid northward thickening of conglomerate in Unit G in the Pilot Range indicates that detritus influx was variable both in terms of source and volume, perhaps as a result of variable subsidence. Probable flaser bedding in Unit G suggests tidally-dominated deposition. The upper, calcareous section of Unit G must have been deposited during a period of low detritus influx, perhaps as a result of a barrier between the major detrital source and the area of deposition. Deposition of the Prospect Mountain Quartzite occurred in a remarkably stable, regionally continuous environment. Pervasive cross stratification in the unit suggests that deposition occurred near shore or on a broad, shallow shelf with strong currents. Its great thickness indicates a gradual and uniform downwarping of the sedimentary basin. Stewart and Poole (1974) suggested the Proterozoic Z and Lower Cambrian strata of the miogeocline were deposited in shallow seas distant from a shoreline because current directions are unidirectional, rather than bidirectional as in a tidal regime.

Tectonic Implications of Proterozoic Z and Lower Cambrian Strata in the Albion Mountains

A complete discussion of the tectonic implications of the correlation between Pilot Range and Albion Mountains strata must include a thorough treatment of the tectonic history of the Albion-Raft River-Grouse Creek metamorphic terrane, a discussion of the character of the metasedimentary rocks, and discussion of geochronologic data. As yet the data for different parts of the terrane are not satisfactorily integrated and many problems remain in all aspects of the geology of the terrane. The scope of this discussion is therefore limited to a brief treatment of the salient features of the terrane and a presentation of some implications of the Proterozoic Z and Lower Cambrian strata on Mount Harrison.

One major problem has been the difficulty of correlating metamorphosed strata to unmetamorphosed counterparts or otherwise determining their ages. Data reported in this paper indicating that strata on Mount Harrison belong to Proterozoic Z and Lower Cambrian sequences represent the first identification of this age strata in the terrane. It has been suggested (Armstrong, 1968; Compton, 1972, 1975; Compton and Todd, 1979) that some of the lower part of the Raft River sequence is Proterozoic Z or Cambrian and a non-miogeoclinal facies, but the data are ambiguous (Crittenden, 1979). One of the major questions that emerges from the correlation made in this paper is whether the Mount Harrison sequence belongs in close association with the Raft River sequence or if it has been tectonically juxtaposed as a result of large-scale low-angle faulting. If the two sequences are closely associated, the lower Raft River sequence must be older than Proterozoic Z because it is dissimilar to the typical Proterozoic Z and lower Paleozoic miogeoclinal section of the region. If the Mount Harrison sequence was carried in with a far-traveled thrust plate, facies changes in Proterozoic Z and Lower Cambrian stata may have been telescoped, and the Raft River sequence may be partly or wholly contemporaneous with the Mount Harrison sequence.

The tectonic relation of the Mount Harrison sequence with the underlying Raft River sequence and the overlying sequence of Robinson Creek is complicated by low-angle faults of uncertain separation. Similar faults occur within the Raft River sequence. Unfortunately these faults were metamorphosed subsequent to or concurrently with their movement, and any characteristics within the fault zone that might indicate magnitude of separation are generally absent.

The sequence of Robinson Creek overlying the Mount Harrison sequence is lithologically similar to the Mount Harrison sequence in containing impure, coarse quartzite with lesser schist and limestone marble, and minor dolomite marble; howver, it is not directly correlative because the distinctive rock types of the Harrison Summit Quartzite and the schist of Willow Creek are not present. My structural investigations on Mount Harrison reveal that the Mount Harrison sequence is overturned, whereas most cross stratification in the sequence of Robinson Creek indicates beds are upright (Miller, 1980). The Robinson Creek is locally tightly folded and in a few places overturned cross-beds occur. A reasonable interpretation is that sequence of Robinson Creek represents the upright limb of a major recumbent fold that has undergone a few kilometers of separation along a fault near its axial plane. In this interpretation the sequence of Robinson Creek overlying the Mount Harrison sequence represents Proterozoic Z strata older than McCoy Creek Group Unit G, based on its general quartzitic character, similar to the lower units of the McCoy Creek Group. The alternative interpretation, that the sequence of Robinson Creek is separated from the Mount Harrison sequence by a major tectonic boundary and therefore is not related, remains a viable hypothesis, but one that I consider to be unlikely because the rock-types are so similar. Approximately 35 km south of Mount Harrison on Middle Mountain (Fig. 2) mapping by R. L. Armstrong has shown that the quartzite assemblage tectonically overlies the lower Raft River sequence and is tectonically overlain by, but closely associated with, Ordovician miogeoclinal strata (Miller and others, 1980), suggesting that the quartzites present on Middle Mountain are Cambrian and/or Ordovician but not the typical miogeoclinal carbonate section. The alternative, that the Ordovician strata are separated from the quartzite assemblage rocks by a major tectonic boundary, remains viable in view of the obscured contact caused by high grade metamorphism and great deformation of the rocks.

Structurally underlying the Mount Harrison sequence is a unit of dark schist, graphitic phyllite and quartzite (labelled "bs" on Figure 4) containing rocks similar to the schist of Mahogany Peaks and Chainman-Diamond Peak Formations undifferentiated that is locally tectonically jumbled by late faulting. The rocks are in part similar to metamorphosed Pioche Formation in the Pilot Range. The unit of dark schist, phyllite, and quartzite is underlain by Pogonip Group rocks, including laminated marble thought to represent metamorphosed Garden City Formation (Lower Ordovician) which in turn overlies metamorphosed Kanosh Shale(?). This overturned Ordovician section is separated by a low-angle fault from underlying Eureka Quartzite, Pogonip Group, and tectonically underlying units of the lower part of the Raft River sequence (Fig. 4), all upright.

The sequence of overturned strata from oldest to youngest on Mount Harrison therefore is: Proterozoic Z Dayley Creek Quartzite and schist of Willow Creek, Proterozoic Z and Lower Cambrian Harrison Summit Quartzite, black schist perhaps correlative with Lower or Middle Cambrian Pioche Formation, and Lower and Middle Ordovician strata. Except for the absence of Middle and Upper Cambrian carbonates this sequence represents the entire upper part of the Proterozoic Z and lower Paleozoic section of the Cordilleran miogeocline. It is possible that the Mount Harrison sequence (Dayley Creek, Willow Creek, and Harrison Summit) is closely associated with underlying and fault-bounded strata of Cambrian(?) and Ordovician age because the stratigraphic section youngs in a consistent direction on both sides of the separating fault. The stratigraphic position of the Mount Harrison sequence in this view was originally between the lower and upper parts of the Raft River sequence. This interpretation requires that the Mount Harrison sequence was tectonically removed from near the base of metamorphosed Ordovician strata, or near the base of the schist of Mahogany Peaks if it correlates with the Pioche Formation, over most of the Albion-Raft River-Grouse Creek metamorphic terrane. In this view, the Proterozoic Z(?) sequence represented by the quartzite assemblage along the west side of the Albion Mountains represents part of the strata missing from the more highly thinned and bedding-plane-faulted central part of the terrane. A perhaps analogous tectonic situation occurs in the southern Grouse Creek Mountains where Silurian and Devonian strata at the southern margin of the terrane occur as thin slices in their normal stratigraphic position (Compton and others, 1977). This interpretation is problematical because no fault has been identified near the base of the Ordovician strata or near the base of the schist of Mahogany Peaks throughout a major part of the terrane (Compton and Todd, 1979). However, less metamorphosed rocks involved in thrusting in fold and thrust belts such as in the North American Cordillera or the Appalachians commonly contain large flat faults that remain within a consistent stratigraphic horizon and lack exotic slices over a large area. Perhaps such faults once broke the strata in the Raft River Mountains area in a similar manner, and are now difficult to identify due to subsequent metamorphism.

The alternative view, that a major tectonic boundary exists between the Mount Harrison sequence and the Ordovician rocks is probable because that tectonic boundary south of Mount Harrison truncates a number of units both in the Raft River sequence and the quartzite assemblage, and because slices of less metamorphosed rock are locally present at this boundary (Armstrong, 1980, written comm.). On Mount Harrison the black schist unit is composed of medium grade schist and graphitic phyllite that appears to be lower grade than the schist, perhaps due to the inhibiting effects of graphite on metamorphic reactions.

Based on the relationships in the Mount Harrison area (Fig. 3), I consider both interpretations of the tectonic contact at the base of the Mount Harrison sequence to be partially supported. Armstrong (1980, written comm.) discusses the consequences of his hypothesis that the boundary is a major tectonic contact. I will briefly discuss some of the consequences of the alternative hypothesis below.

The hypothesis for a close relation between the Mount Harrison sequence and the miogeoclinal Ordovician section within the Raft River sequence leaves two alternatives for the relation between the miogeoclinal sequence and the remaining five or six (depending on whether the schist of Mahogany Peaks is included) units of the lower Raft River sequence: 1, The miogeoclinal section was originally spatially unrelated to other units in the lower Raft River sequence and was juxtaposed by considerable movement on low-angle faults; or 2, all of the rocks in thrust sheets in the metamorphic terrane moved only a few tens of kilometers on low-angle faults, and thus non-miogeoclinal facies of strata cannot be present. Where faults are definitely recognized within the lower part of the Raft River sequence they cannot displace strata significantly because units in both autochthonous and allochthonous positions are virtually identical. This is tenuous evidence in support of the second alternative.

The first alternative implies that relations between the lower Raft River sequence and overlying units of the Cordilleran miogeocline are indeterminate. Therefore, part of the Raft River sequence could represent Proterozoic Z or Cambrian strata of remarkably different facies than the miogeoclinal section seen in the Mount Harrison sequence. This interpretation is supported by a poorly defined 570 m.y. Rb-Sr isochron determined from samples of several different metasedimentary units in the Raft River sequence (Armstrong, 1976) and by the lack of an early metamorphic event in the lower Raft River sequence similar to that observed in Lower Proterozoic rocks elsewhere in the region.

The second alternative implies that the lower Raft River sequence is not Proterozoic Z or Cambrian and it is therefore most probably older. Data supporting a possible Proterozoic X age for these units are summarized by Crittenden (1979).

Recognizing that Proterozoic Z and Lower Cambrian strata are present in the Albion-Raft River-Grouse Creek metamorphic terrane adds support to the concept that a thick miogeoclinal section similar to sections exposed in nearby ranges once existed in the metamorphic terrane. The existence of such a miogeoclinal section remains unproved, however, because details of the tectonic history in this terrane are unresolved. The relation of the lower units in the Raft River sequence to miogeoclinal strata of the upper part of the Raft River sequence also remains unresolved.

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FIGURE CAPTIONS

Fig. 1. Sketch map of the northeastern Great Basin area showing mountain ranges largely composed of pre-Tertiary sedimentary rocks (dot pattern). Proterozoic Z rocks are shown by heavy shading. Data from Stokes (1963), Hope and Coats (1976), Bond (1978) and Blick (1979).

Fig. 2. Generalized geologic map of Albion Mountains and vicinity, modified from Armstrong and others (1978) and Miller (1978). Outlined area indicates Mount Harrison map area of Figure 3. Autochthon includes Green Creek Complex (Precambrian W), and Elba Quartzite and schist of the Upper Narrows (Proterozoic or Paleozoic). Paleozoic and Proterozoic(?) metasedimentary rocks include quartzite of Yost, schist of Stevens Spring, quartzite of Clark Basin, schist of Mahogany Peaks, Pogonip Group, Eureka Quartzite, and Chainman-Diamond Peak Formations undifferentiated. Mount Harrison sequence includes the Dayley Creek Quartzite, schist of Willow Creek and Harrison Summit Quartzite. Quartzite sequence includes all rocks in the quartzite assemblage as defined in the text, exclusive of units in the Mount Harrison sequence.

Fig. 3. Generalized geologic map of Connor Ridge and Mount Harrison 7 1/2' quadrangles (Miller, 1978; unpubl. map, 1979). Locations of cross sections AA' and BB' of Figure 4 are indicated. Paleozoic and Precambrian metasedimentary rock unit of map is the upper part of the Raft River sequence; autochthonous metasedimentary rock unit is the lower part. Sequence of Robinson Creek and Mount Harrison sequence make up the quartzite assemblage.

Fig. 4. Structure sections of the Mount Harrison sequence and underlying units in Albion Mountain showing inferred tectonic relations. Units are described more completely in text; all age designations are tentative except for the Green Creek Complex (Armstrong, 1976). Unit X(?) of Fig. 3 is Elba Quartzite and schist of the Upper Narrows in this figure; Unit PzPC is comprised of Ok, Ogc, bs and Xcb.

Fig. 5. Correlation chart showing nomenclature for the Mount Harrison sequence and correlations with rock units in the Pilot Range proposed in this report. The structural and stratigraphic interpretations for the Mount Harrison sequence of Armstrong (1980, written comm.) and Miller (this paper) are indicated. Armstrong (1968) considered the sequence of quartzite and schist on Mount Harrison to young from Conner Creek Formation to Dayley Creek Quartzite, but later revised the younging direction based on overturned cross-beds in much of the sequence (Armstrong, 1970). His present interpretation (Armstrong, 1980, written comm.) makes no assumptions about the relative ages of the Harrison Summit and Dayley Creek.

Fig. 6. Photographs of characteristic rock types in schist of Willow Creek. a) Rip-up clasts in coarse quartzite matrix from Quartzite I member. b) Thinly interbedded marble and phyllite with pronounced crosscutting foliation from Schist III member. Pencil is 15 cm long.

Fig. 7. Geological sketch map of the Pilot Range. Geology of the central part of the range after Miller (unpubl. maps, 1979); northern and southern parts from Blue (1960), Stokes (1963), O'Neill (1968), Hope and Coates (1976), and Miller (unpub. maps, 1980). Location of Pilot Peak and Patterson Pass areas outlined by dashed lines.

Fig. 8 Generalized geologic map of the Pilot Peak area, Pilot Range (see Fig. 7 for location). Measured sections are numbered as described in the text. Location of structure section AA' indicated.

Fig. 9. Photographs of characteristics of Unit G of the McCoy Creek Group. a) Phyllite rip-up wedges in pebbly quartzite at base of Unit G. b) Interbedded marble and phyllite. Pencil is 15 cm long.

Fig. 10. Generalized geologic map and structure section of area south of Patterson Pass (see Fig. 7 for location), Pilot Range. Stratigraphic markers in conglomerate member of Unit G of McCoy Creek Group are indicated by dot-dash lines. Structure symbols are identified in Figure 8. Sections from which thicknesses were determined are numbered and referred to in the text.

Fig. 11. Tentative correlation of stratigraphic sections from Pilot Range localities and Albion Mountains.

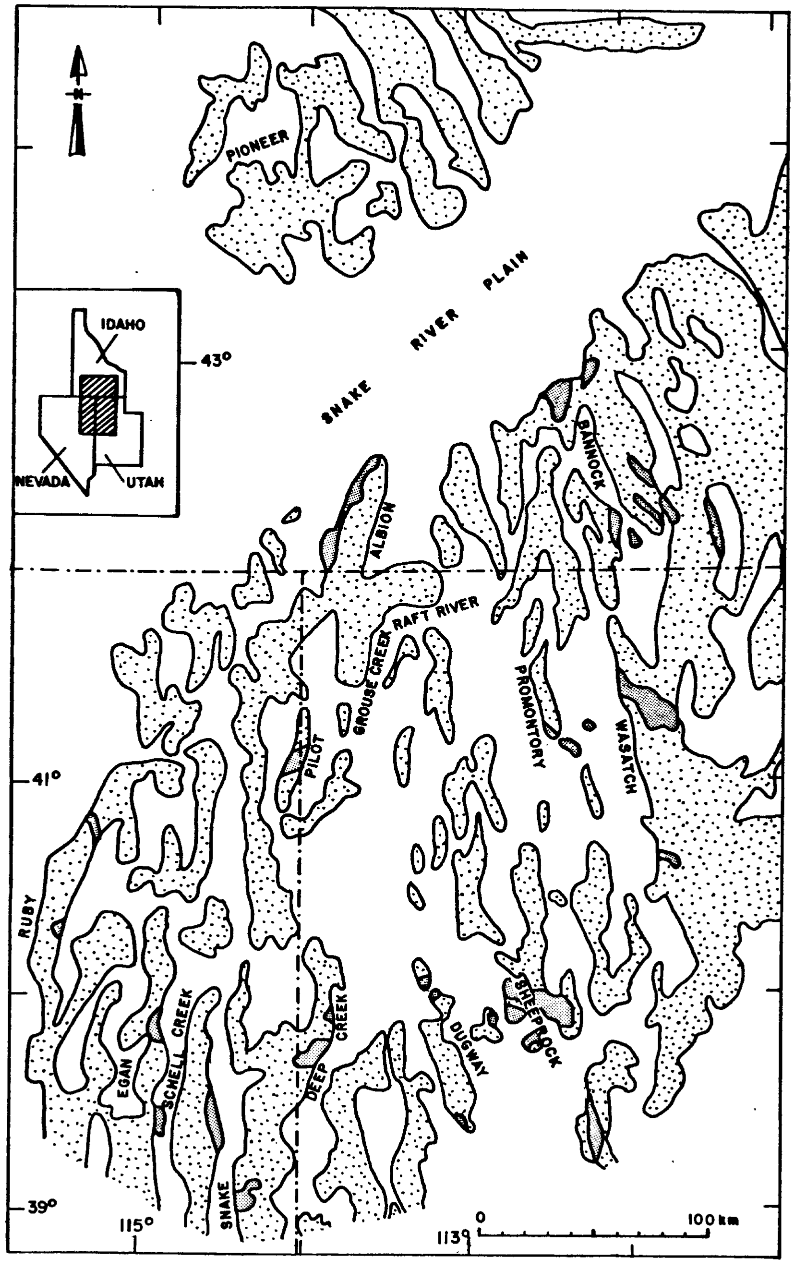

N
IDAHO
NEVADA
UTAH
43°
41°
39°
115°
113°
0
100 km
PIONEER
SNAKE RIVER PLAIN
BANNOCK
ALBION
RAFT RIVER
GROUSE CREEK
PROMONTORY
WASATCH
PILOT
RUBY
EGAN
SCHELL CREEK
SNAKE
DEEP CREEK
DUGWAY
SHEEPROCK

Fig. 1

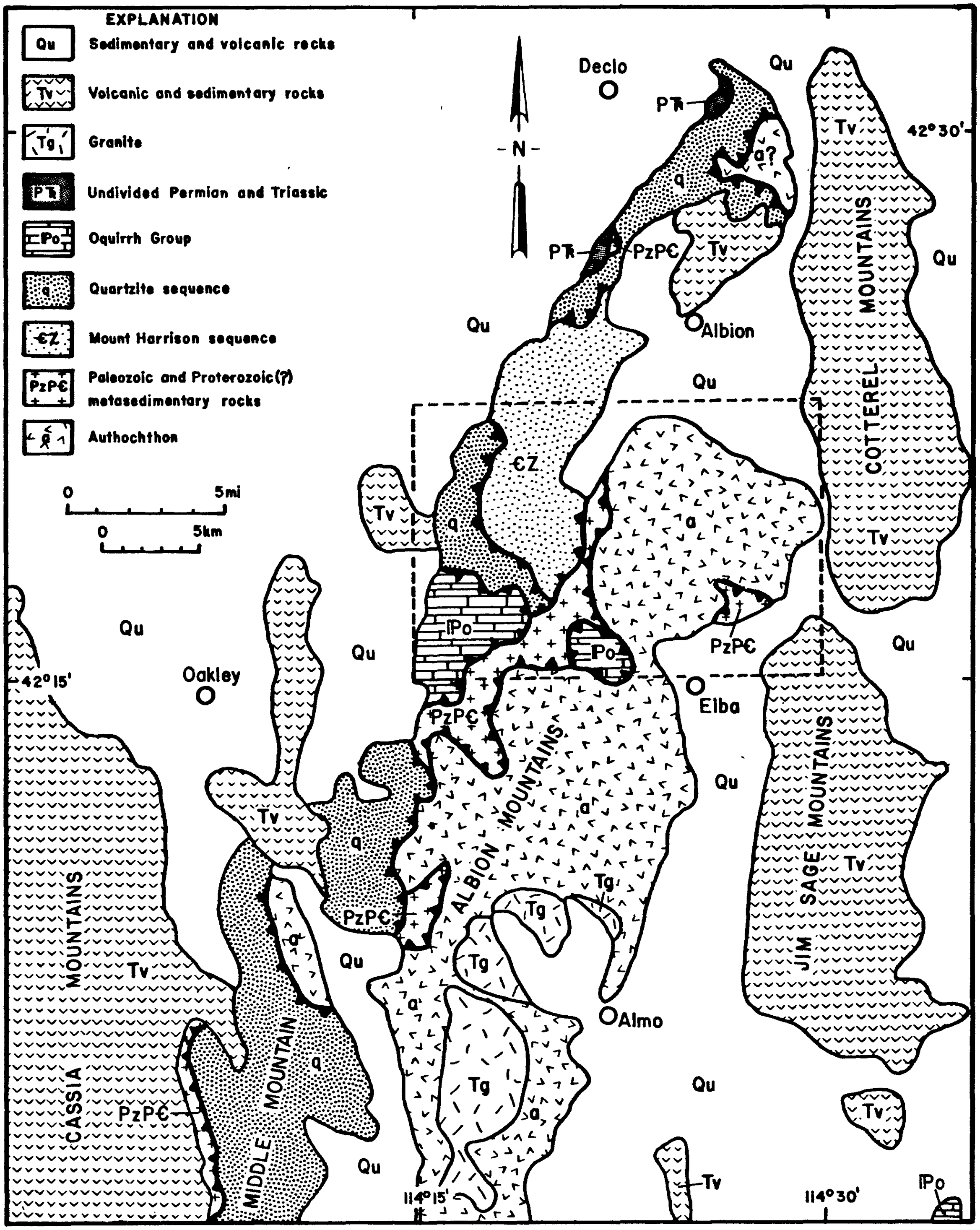

EXPLANATION
Qu Sedimentary and volcanic rocks
Tv Volcanic and sedimentary rocks
Tg Granite
P₸ Undivided Permian and Triassic
IPo Oquirrh Group
q Quartzite sequence
€Z Mount Harrison sequence
PzP€ Paleozoic and Proterozoic(?) metasedimentary rocks
a Authochthon
0 5mi
0 5km
N
Declo
Albion
Oakley
Elba
Almo
COTTEREL MOUNTAINS
ALBION MOUNTAINS
JIM SAGE MOUNTAINS
CASSIA MOUNTAINS
MIDDLE MOUNTAIN
42°30'
42°15'
114°15'
114°30'

Fig. 2.

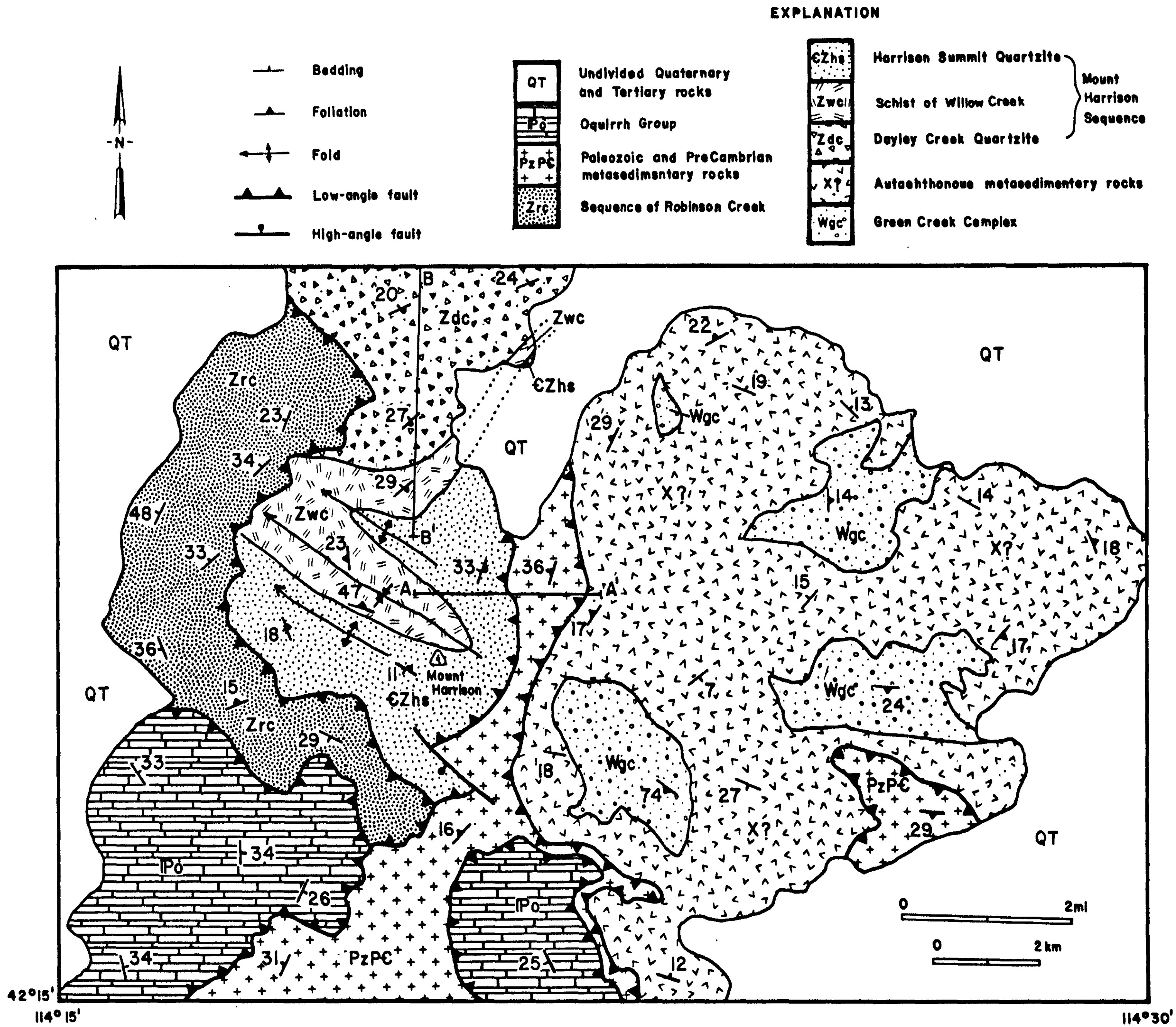

EXPLANATION
N
Bedding
Foliation
Fold
Low-angle fault
High-angle fault
QT Undivided Quaternary and Tertiary rocks
IPo Oquirrh Group
PzP€ Paleozoic and PreCambrian metasedimentary rocks
Zrc Sequence of Robinson Creek
€Zhs Harrison Summit Quartzite
Zwc Schist of Willow Creek
Zdc Dayley Creek Quartzite
Mount Harrison Sequence
X? Autochthonous metasedimentary rocks
Wgc Green Creek Complex
Mount Harrison
0 2mi
0 2km
42°15'
114°15'
114°30'

Fig. 3

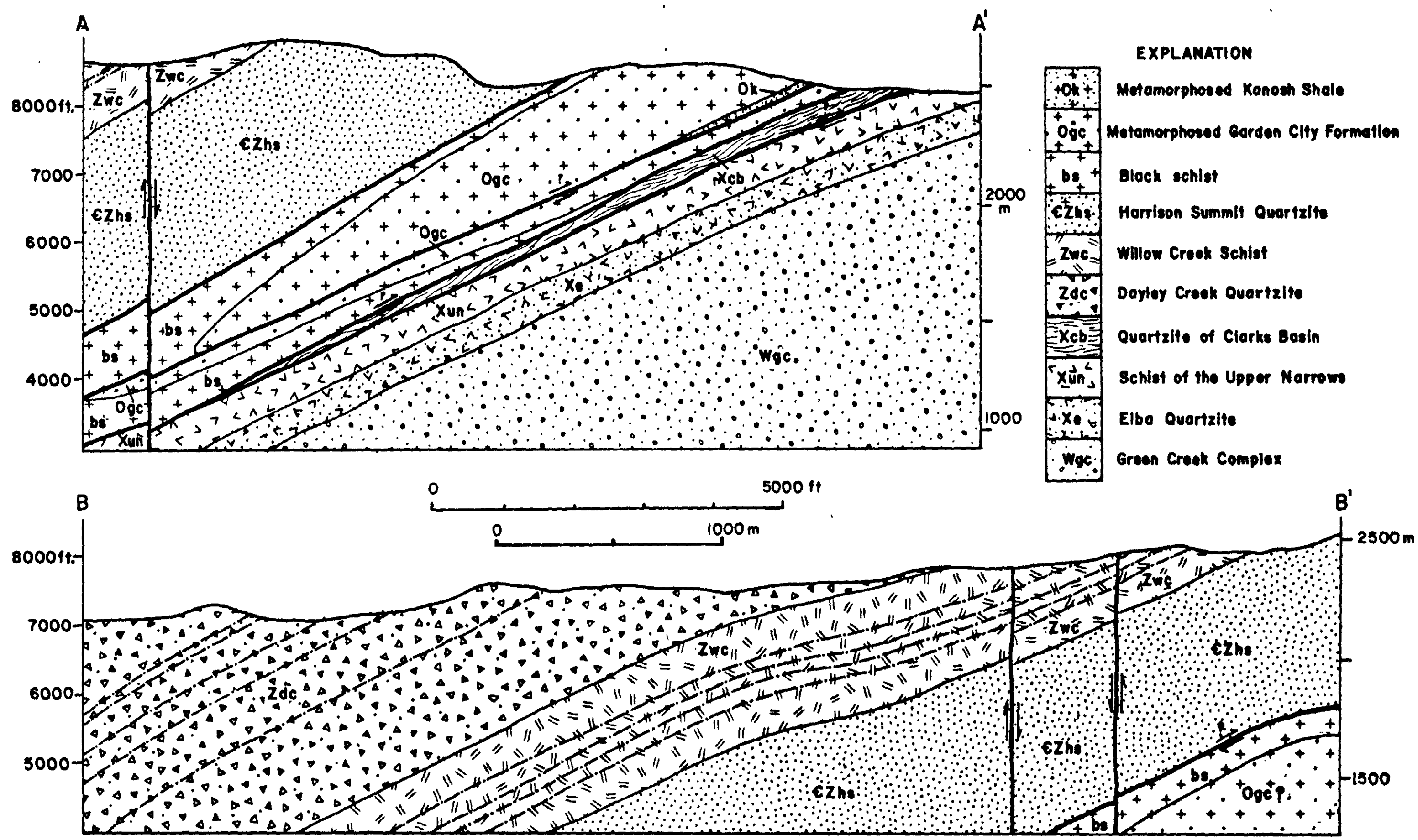

A
A'
B
B'
8000ft.
7000
6000
5000
4000
2000 m
1000
2500m
1500
0
5000 ft
1000 m
EXPLANATION
Ok Metamorphosed Kanosh Shale
Ogc Metamorphosed Garden City Formation
bs Black schist
€Zhs Harrison Summit Quartzite
Zwc Willow Creek Schist
Zdc Dayley Creek Quartzite
Xcb Quartzite of Clarks Basin
Xun Schist of the Upper Narrows
Xe Elba Quartzite
Wgc Green Creek Complex
€Zhs
Zwc
Ogc
Xcb
Xun
Xe
Wgc
Zdc
Ogc?

Fig. 4

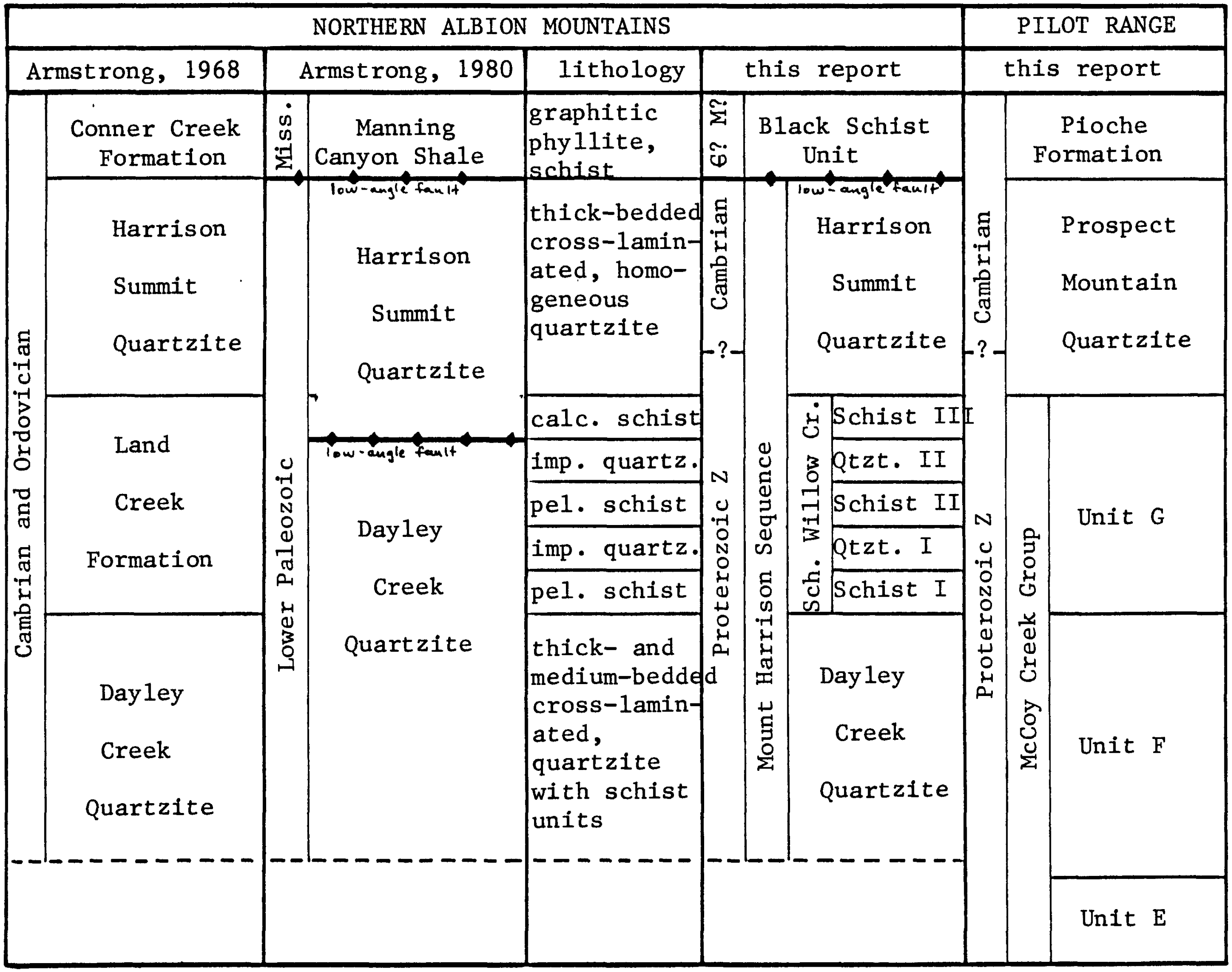

NORTHERN ALBION MOUNTAINS
PILOT RANGE
Armstrong, 1968
Armstrong, 1980
lithology
this report
this report
Cambrian and Ordovician
Conner Creek Formation
Harrison Summit Quartzite
Land Creek Formation
Dayley Creek Quartzite
Miss.
Lower Paleozoic
Manning Canyon Shale
low-angle fault
Harrison Summit Quartzite
low-angle fault
Dayley Creek Quartzite
graphitic phyllite, schist
thick-bedded cross-laminated, homogeneous quartzite
calc. schist
imp. quartz.
pel. schist
imp. quartz.
pel. schist
thick- and medium-bedded cross-laminated, quartzite with schist units
6? M?
Cambrian
?
Proterozoic Z
Black Schist Unit
low-angle fault
Mount Harrison Sequence
Harrison Summit Quartzite
Sch. Willow Cr.
Schist III
Qtzt. II
Schist II
Qtzt. I
Schist I
Dayley Creek Quartzite
Cambrian
?
Proterozoic Z
McCoy Creek Group
Pioche Formation
Prospect Mountain Quartzite
Unit G
Unit F
Unit E

Fig. 5

a

b

Fig. 6

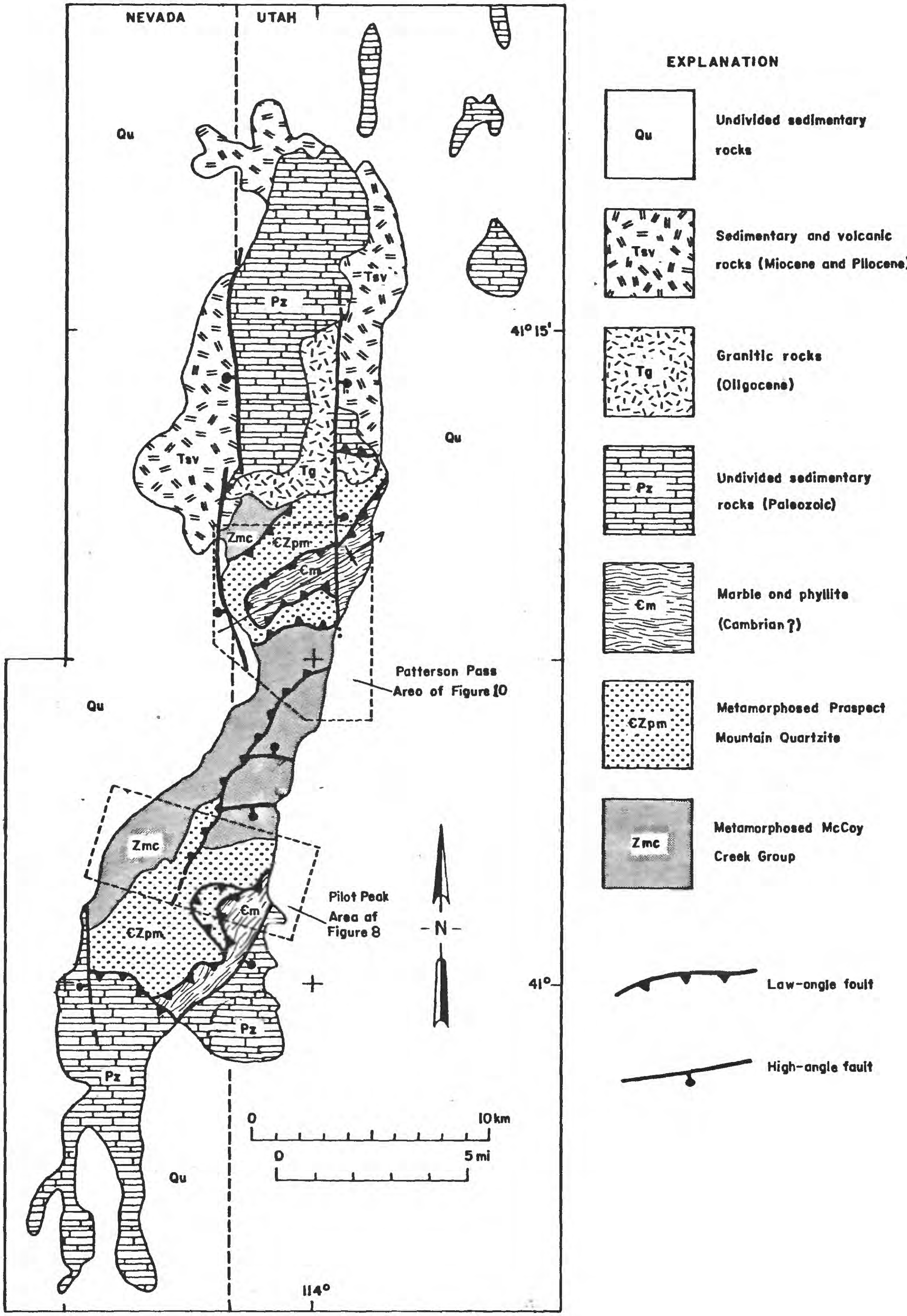

NEVADA
UTAH
Qu
Tsv
Pz
Tg
Zmc
€Zpm
€m
41° 15'
41°
114°
Patterson Pass
Area of Figure 10
Pilot Peak
Area of
Figure 8
N
0
10 km
0
5 mi
EXPLANATION
Undivided sedimentary rocks
Sedimentary and volcanic rocks (Miocene and Pliocene)
Granitic rocks (Oligocene)
Undivided sedimentary rocks (Paleozoic)
Marble and phyllite (Cambrian ?)
Metamorphosed Prospect Mountain Quartzite
Metamorphosed McCoy Creek Group
Low-angle fault
High-angle fault

Fig. 7

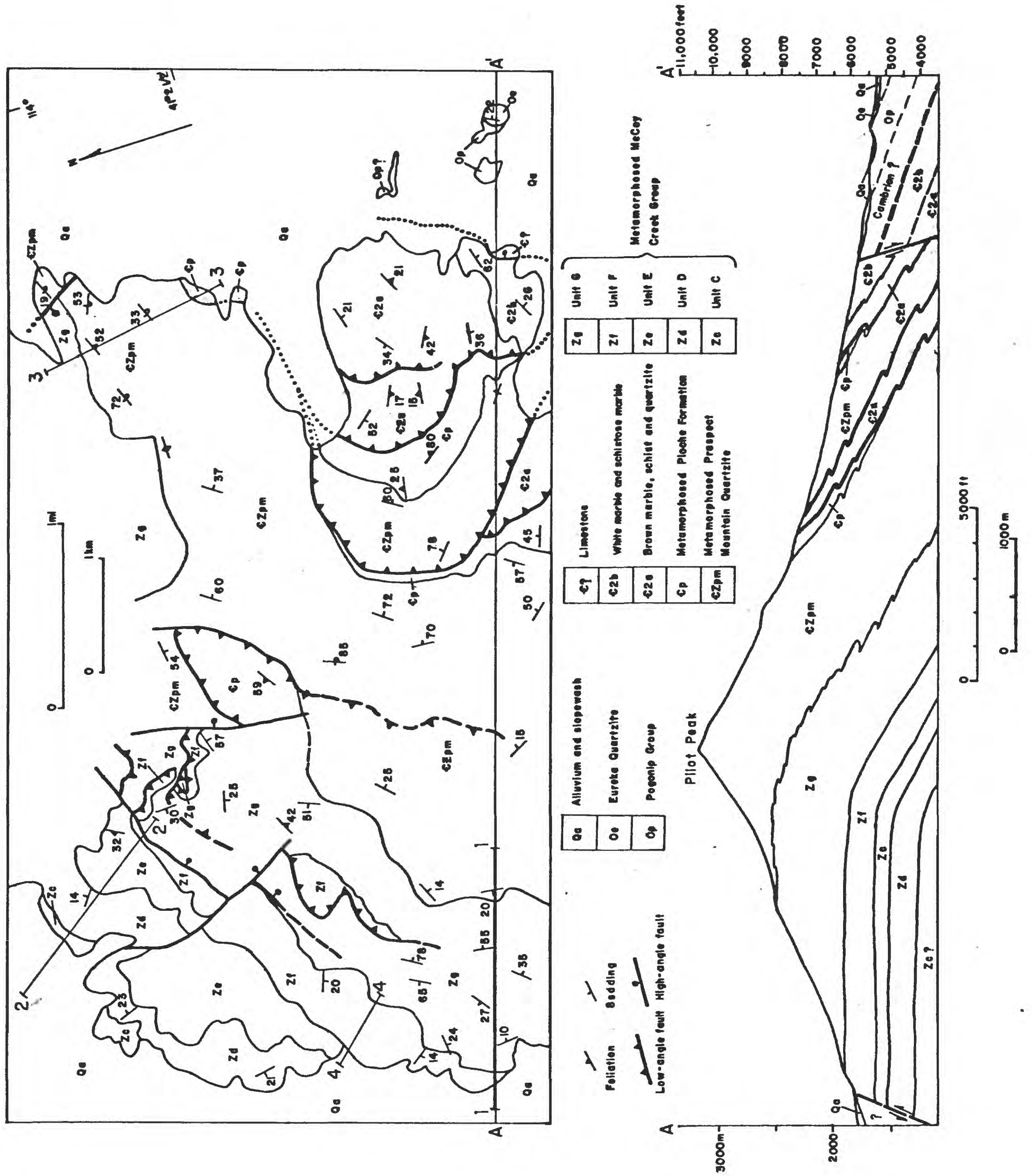
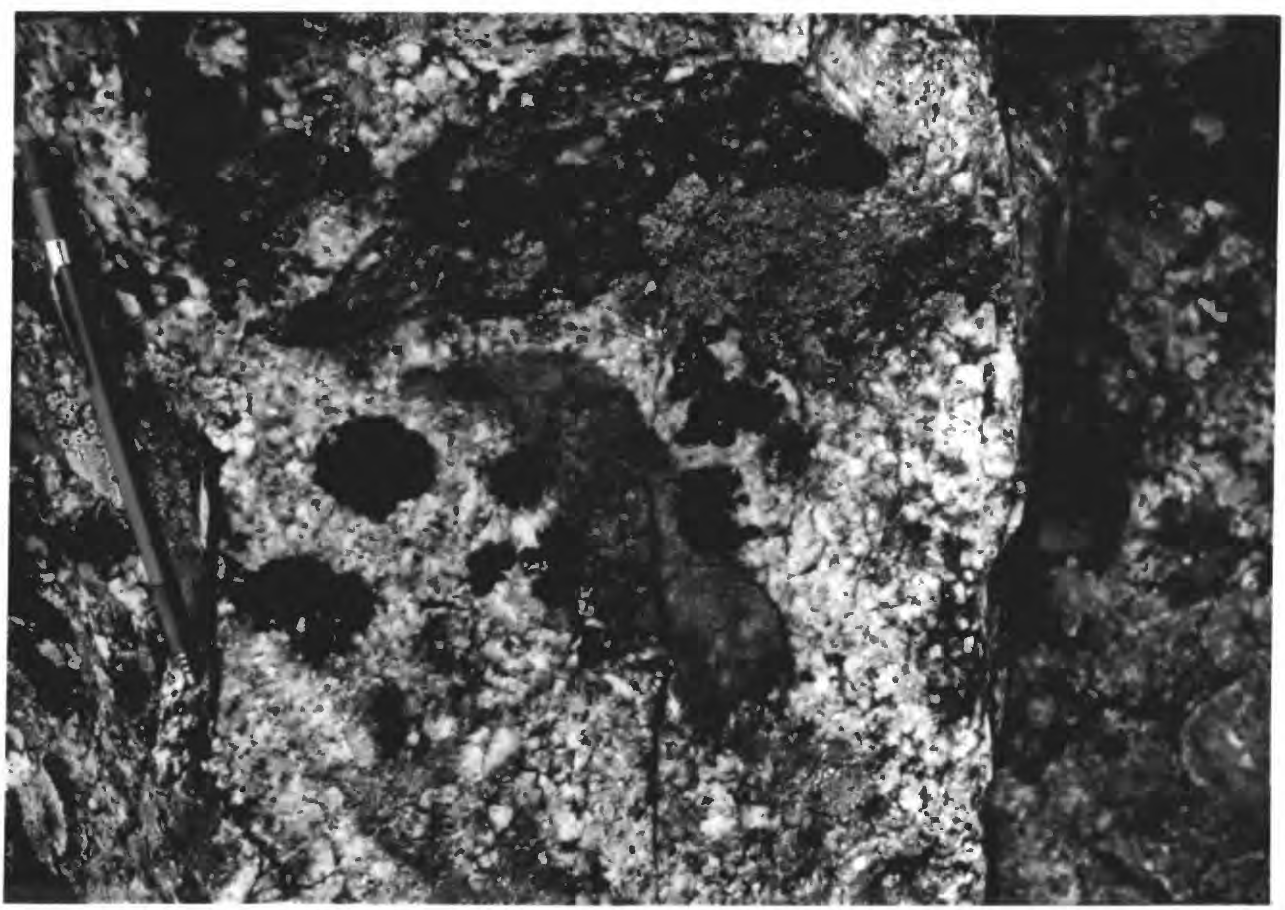

Qa Alluvium and slopewash
Oe Eureka Quartzite
Op Pogonip Group
€? Limestone
€2b White marble and schistose marble
€2a Brown marble, schist and quartzite
€p Metamorphosed Pioche Formation
€Zpm Metamorphosed Prospect Mountain Quartzite
Zg Unit G
Zf Unit F
Ze Unit E
Zd Unit D
Zc Unit C
Metamorphosed McCoy Creek Group
Foliation
Bedding
Low-angle fault
High-angle fault
Pilot Peak
Cambrian ?
0 1 mi
0 1 km
0 5000 ft
0 1000 m
A
A'
3000m
2000
11,000 feet
10,000
9000
8000
7000
6000
5000
4000

Fig. 8

b



a

Fig. 9

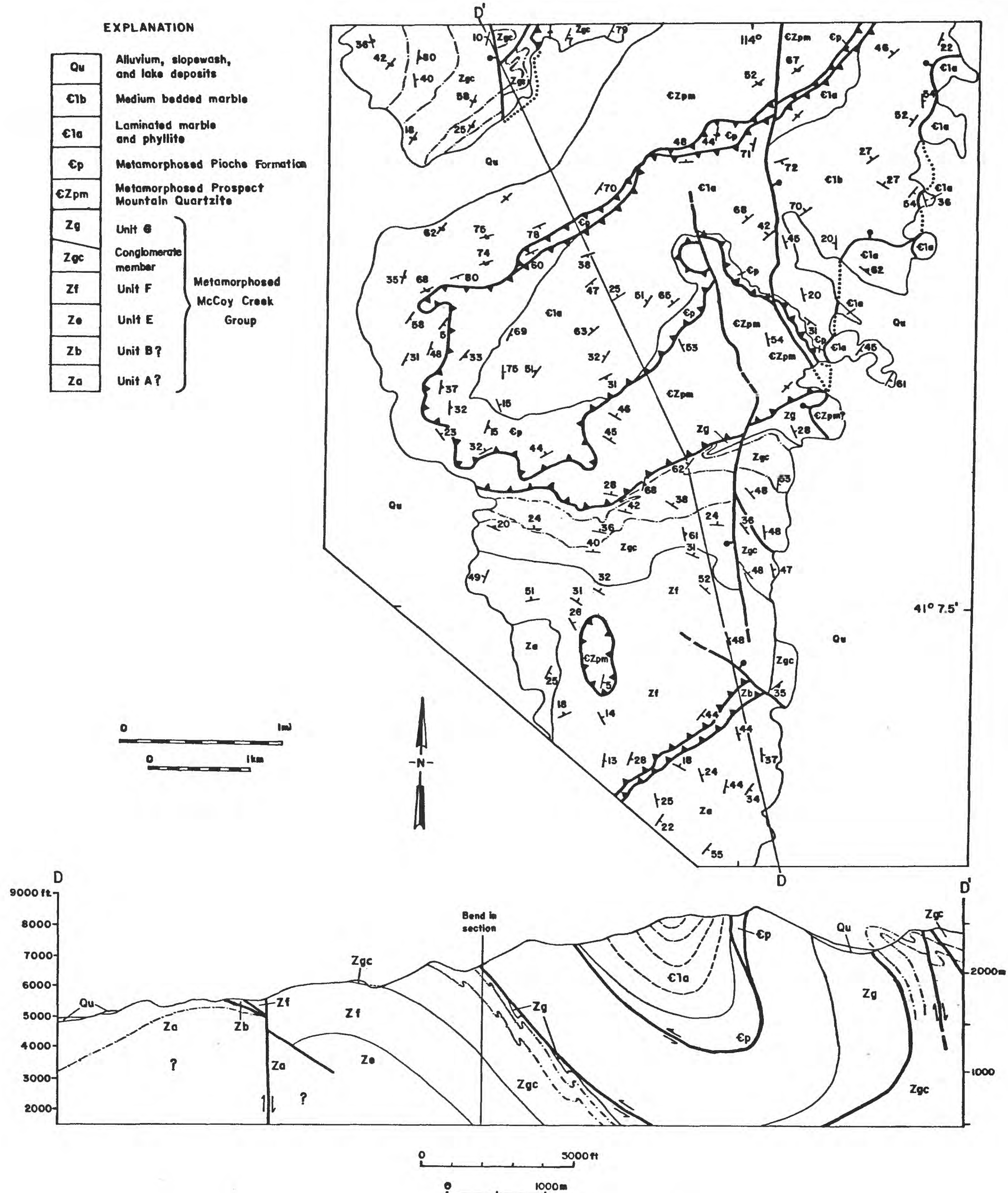
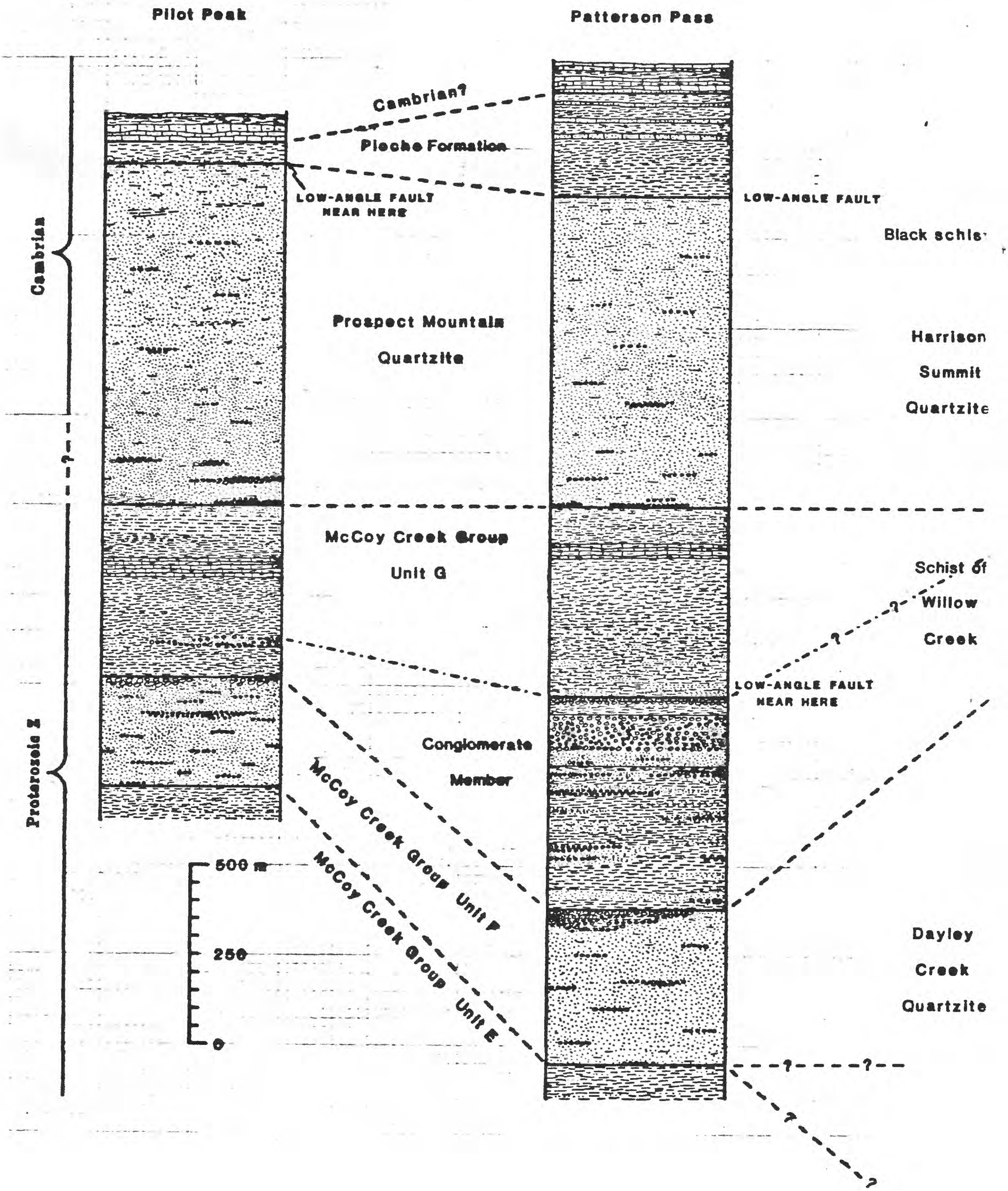

EXPLANATION
Qu Alluvium, slopewash, and lake deposits
€1b Medium bedded marble
€1a Laminated marble and phyllite
€p Metamorphosed Pioche Formation
€Zpm Metamorphosed Prospect Mountain Quartzite
Zg Unit G
Zgc Conglomerate member
Zf Unit F
Ze Unit E
Zb Unit B?
Za Unit A?
Metamorphosed McCoy Creek Group
0 1mi
0 1km
N
114°
41° 7.5'
D
D'
9000 ft
8000
7000
6000
5000
4000
3000
2000
Bend in section
2000m
1000
0 5000ft
0 1000m

Fig. 10

PILOT RANGE


Pilot Peak
Patterson Pass
Cambrian?
Pioche Formation
LOW-ANGLE FAULT NEAR HERE
LOW-ANGLE FAULT
Black schist
Cambrian
Prospect Mountain Quartzite
Harrison Summit Quartzite
McCoy Creek Group Unit G
Schist of Willow Creek
LOW-ANGLE FAULT NEAR HERE
Conglomerate Member
Proterozoic Z
McCoy Creek Group Unit F
McCoy Creek Group Unit E
500 m
250
0
Dayley Creek Quartzite

11B

ALBION MOUNTAINS

Mount Harrison