

Metamorphic infrastructure in the northern Ruby, Mountains, Nevada

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Abstract

The Ruby Mountains metamorphic complex in northeastern Nevada exposes Paleozoic strata that are metamorphosed to sillimanite grade, migmatized, and recumbently folded. Nappes are variously overturned to the east, north, south, and west. The deeper part of this infrastructure is a migmatitic zone pervaded by pegmatitic two-mica granite. A structurally higher transition zone underwent extreme tectonic flattening and some thrusting as the mobile infrastructure rose buoyantly against more rigid suprastructure. Relief by flow and stretching to the WNW and ESE resulted in a regionally constant lineation in this transition zone. The age of metamorphism is uncertain but may be Jurassic.

Introduction

The Ruby Mountains metamorphic complex lies in the Cenozoic basin-and-range province, in the western hinterland of the Mesozoic Sevier overthrust belt and east of the Paleozoic Antler thrust belt (fig. 1). Latest Precambrian to Devonian carbonate and quartzite units in the complex are metamorphosed, intimately injected by granite, and recumbently folded. Extensive migmatization and the ductile style of deformation support the concept that a mobile metamorphic infrastructure developed in

this area of the Cordilleran miogeocline which contrasts with more rigidly deformed suprastructural rocks higher in the pile, as originally suggested by Armstrong and Hansen (1966; Howard, 1971; Snoke, 1974, 1975, in press). Nearby areas expose equivalent strata that are relatively little metamorphosed. This paper briefly summarizes the tectonic style of the infrastructure in the northern Ruby Mountains, determined from detailed structural data and analysis (Howard, 1966; Smith and Howard, 1977; and unpublished mapping).

Setting

The metamorphic complex (fig. 2) is exposed in the northern Ruby Mountains and adjacent East Humboldt Range, which are horsts, and in the uparched Wood Hills described by Thorman (1970). Rocks in the migmatitic cores of the Ruby and East Humboldt Ranges are metamorphosed to sillimanite-muscovite zone. They are flanked along the west by a transition zone, largely in lower amphibolite facies, that is characterized by blastomylonitic fabrics with a regional west-northwest trending streaky lineation.

Figure 3 shows the area of this report. The part of the Ruby Mountains north of this area is transition zone containing low-angle ductile faults (fig. 2), overlain by fault sheets of upper Paleozoic sedimentary rocks (Snelson, 1957; Snoke, 1974, 1975, in press, this volume). South of the area of figure 3, granitic rocks in a anticlinal high largely separate the metamorphic complex from Paleozoic sedimentary rocks in the

southern Ruby Mountains (Willden and Kistler, 1969). A generalized geologic map and sections of the Ruby Mountains by Howard and others (in press) show relations among these areas.

The metasedimentary stratigraphy of the northern Ruby Mountains is summarized in table 1. Correlations are based on comparison of the lithologic sequence with strata elsewhere in eastern Nevada (Howard, 1971). Fossils have not been found in the northern Ruby Mountains to confirm these correlations, but fossils have been found that date metasedimentary rocks in the Wood Hills (Thorman, 1965, 1970). Mineral assemblages (table 1) indicate that amphibolite-facies metamorphism was of low-pressure or low-pressure intermediate type (Miyashiro, 1961).

Granites

The complex as exposed in the northern Ruby Mountains is a migmatite terrane in which granitic rocks, intimately intermixed with the metasedimentary rocks, account for about half the exposed volume, yet do not obliterate the stratigraphic sequence and structure. Metasediments in the highest levels of the complex are intruded only by sparse pods of pegmatite, much as in the nearby Wood Hills (Thorman, 1970). The percentage of granitic material increases downward until gneissic pegmatitic granite occupies the lowest structural levels with few or no metasedimentary relics. The predominant granitic rock is leucocratic two-mica pegmatitic granite (varying to trondjemite) that occurs in sills, dikes, and irregular bodies (table 2). Other types include biotite adamellite, two-mica adamellite, and

biotite granodiorite. Garnet is common in these rocks. Many of them are gneisses. Emplacement of the granitic rocks was largely passive and spanned the period of penetrative deformation.

The pegmatitic granite is extensively exposed (fig. 2) just south of my area. Willden and Kistler (1969; Howard and others, in press) assign it there a Jurassic Rb-Sr age (160 m.y.) and report that it is intruded by two-mica granite of Cretaceous Rb-Sr age (82 m.y.) and by Oligocene (38 m.y.) granodiorite pluton of Harrison Pass (Willden and others, 1967).

Recumbent Folds

The dominant structures in the part of the range studied (fig. 3) are large recumbent folds (figs 4 and 5). Foliation parallels the axial surfaces of these folds, and dips gently over large areas. The folds vary widely in trend and vergence, but generally plunge northward with the result that higher structural levels are exposed in that direction. The principal anticlinal folds and their maximum crest-to-trough amplitudes are: the southeastward overturned Lamoille Canyon nappe (9 km), the northeastward overturned King Peak nappe (6 km), the Hidden Lakes uplift (>1 km), and the westward overturned Soldier Creek nappe (4 km). These large folds are paralleled by small parasitic folds and by mineral lineations.

The tightly appressed Lamoille Canyon nappe (fig. 4) is well exposed in many deep glaciated canyons. It folds Prospect Mountain Quartzite (Cambrian and Precambrian Z) and marble of Verdi Peak (Cambrian and Ordovician) previously duplicated by the

premetamorphic Ogilvie thrust fault (Smith and Howard, 1977). Two bodies of orthogneiss occupy the core of the nappe beneath the level of the folded thrust: biotite granodiorite gneiss of Seitz Canyon is enveloped by Prospect Mountain Quartzite, and two-mica garnet adamellite gneiss of Thorpe Creek is enveloped by marble (fig. 4). The nappe arches gently parallel to its north-trending axis, so that the nose bends down eastward. Coaxial eddy-like and refolded small folds suggest that the nappe began to roll over on itself as it grew. To the south the nappe hinge bends abruptly to the west, the nappe decreases in amplitude, and becomes locally detached. In its southwesternmost exposures, in the transition zone, the nappe becomes a thrust sheet with a displacement of only a kilometer (Smith and Howard, 1977).

The King Peak nappe displaces Prospect Mountain Quartzite northeastward over marble of Cambrian and Ordovician age (fig. 4, C-C'). The south end of the area mapped in figure 3 (Rattlesnake Canyon) exposes three, perhaps four synclinal roots beneath the nappe; at least one of these is partly detached by thrusting. Quartzite in the nappe is exposed continuously for 1 km in front (north) of its root(s), and outliers lie as far as 6 km north and a little lower than the root. Those beyond 4 km rest in thrust contact on younger but higher grade marbles, suggesting that the nappe slid down on them. A plexus of late metamorphic thrust slivers lies at the west foot of the range where the King Peak nappe, if it projects westward, opposes the southward overturned

Lamoille Canyon nappe (Smith and Howard, 1977).

The Hidden Lakes uplift is a doubly plunging, mostly upright anticline entirely within the sillimanite-zone core of the complex (fig. 5). Foliation in the Prospect Mountain Quartzite and overlying marble wraps around the uplift, and locally small folds are coaxially refolded. In the north, the uplift overhangs westward so that the opposing Lamoille Canyon nappe nestles against it (fig. 4, A-A'). Southward, the overhang disappears as the uplift diverges away from the nappe, and the synclinal complex of high-grade rocks between them becomes many kilometers broad. Cambrian and Ordovician marble within the synclinal complex is thus greatly thickened. Small folds and other fabric elements vary in orientation suggesting variable flow directions, perhaps related to bouyant(?) rising of quartzite in the uplift and sinking of marble in the synclinal complex. Variable flow directions and supple style of deformation thus characterize the high-grade core of the metamorphic infrastructure. The rocks in this core are coarsely crystalline and annealed (fig. 6b), indicating that heating kept pace with and outlasted deformation.

The Soldier Creek nappe is rooted in a steeply dipping migmatitic zone east of the Hidden Lakes uplift, and is folded some 4 km westward down over the uplift and the Lamoille Canyon nappe. It is a tight fold that inverts rocks ranging in age from Cambrian and Precambrian Z (Prospect Mountain Quartzite) to Devonian (marble probably equivalent to the Guillemette Formation). Most of the nappe is in the transition zone, and

Snoke (1974) has found evidence that the nappe is locally detached. The underlying synclinal hinges of metamorphosed Ordovician-Cambrian limestone, Ordovician Eureka Quartzite, Devonian to Ordovician dolomite, and Devonian limestone show a complex pattern of extraordinary fold disharmony and variation in trend (fig. 5). At the level of the Eureka Quartzite the nappe decreases in amplitude to 0.5 km and the hingeline changes direction 180° . Despite this disharmony, all fold hinges in the nappe and underlying syncline have in common a component of vergence to the west-northwest. This sense is opposite to that of the underlying Lamoille Canyon nappe, although it matches the sense shown by many small folds on the upper limb of that nappe; their reverse sense recalls spruce-tree folds of New England (Skelan, 1961; Thompson and Rosenfeld, 1951).

Transition zone

Along the west flank of the range, the Lamoille Canyon and Soldier Creek nappes are both so highly attenuated that the stratigraphic sequence is thinned to as little as one fifteenth to one twentieth of the original thickness. This extreme thinning occurred during metamorphism and partly outpaced crystallization, as indicated by blastomylonitic textures in augen gneisses, flaggy quartzite (fig. 6,a) and marble. Quartzofeldspathic rocks have prominent foliation and a pervasive streaky lineation (fig. 7). The transition zone is composed of rocks showing these features characteristic of dominant strain. The lineation is formed by highly elongate quartz and other

minerals; crystalline quartz and mica mortar typically surrounds more resistant feldspar augen. The lineation has a constant orientation west-northwest, perpendicular to the main trend of the Lamoille Canyon nappe.

The transition zone encompasses parts of several folds, not all at the same structural level (figs. 2, 4). For example, the streaky lineation occurs in the nose and part of the root zone of the Soldier Creek nappe in the north, in both limbs but not the nose of the lower level Lamoille Canyon nappe, and in pegmatitic granite below the mapped nappes in the southwest corner of the area shown in figure 3. Despite their mylonitic character, rocks of the transition zone deformed at high temperature, and lack effects of retrograde metamorphism. The sillimanite isograd generally lies near the base of the transition zone and cuts obliquely across structures, which suggests that high temperatures continued to the end of deformation.

The blastomylonitic fabrics that characterize the transition zone are believed to result from the extraordinary tectonic flattening and stretching. This fabric system is mesocopically orthorhombic in symmetry; the few small folds that parallel the streaky lineation are tightly appressed in the plane of the subhorizontal foliation, and show no consistent vergence. The symmetry is compatible with an origin for the foliation and lineation by orthorhombic thinning and stretching, that is, pure strain. The strain was broadly synchronous with nappe folding,

for the stretching lineation is commonly folded by folds parasitic to the Lamoille Canyon nappe, yet an unfolded aplite dike was affected by the lineation, and both limbs of the nappe have been flattened (fig. 4).

Calc-silicate marbles in the transition zone typically show folds parasitic to the nappes, even though some on the upper limb of the Lamoille Canyon nappe show a reverse or spruce-tree sense of vergence. Flow slip lines as determined by Hansen's (1971) method using vergence separation arcs in the Lamoille Canyon nappe near and in the transition zone strike west-northwest (Howard, 1966). This orientation holds even in the southern part of the nappe, where the nappe and its most prominent parasitic folds and lineation veer obliquely to or subparallel to flow line (Howard, 1968). The separation arcs containing the flow lines, taken cumulatively, show that slip flow to the WNW and ESE paralleled the direction of stretching shown by the streaky lineation (fig. 8).

The WNW direction of tectonic transport was used on a large scale by the Soldier Creek nappe as indicated by the map pattern of its hinge lines (fig. 5). Furthermore, slickensides on small thrust faults between the Lamoille Canyon and King Peak nappes are parallel to the streaky lineation and further indicate tectonic transport in this orientation. Rocks in the transition zone apparently squeezed outward by both thinning and shear to the east-southeast and west-northwest. This is a pattern of extending flow (Price, 1972). It suggests gravitational

compression with a single direction of relief which was perpendicular to Cordilleran trends.

Discussion

The variability in fold styles and trends and their independence at different structural levels is striking. Even so, the orientation of flow and extension within the transition zone was surprisingly uniform. The infrastructure core, with its high temperatures and abundant granitic material, had low strength and involved large-scale rock flow. Its deformation was probably driven by thermal and gravitation instabilities; the opposing overturns of the nappes argues against lateral compression. Crustal stretching cannot be ruled out, for metasedimentary volumes in known folds are less than original stratigraphic thicknesses would allow. Disharmony probably developed as the infrastructure rose buoyantly against a more rigid suprastructure (fig. 9). Relief occurred at this level by outward flow resulting in development of the transition zone, thus flattening folds that originated below. Some of these movements outspaced metamorphic crystallization resulting in detached folds. The shear and extension direction is remarkably constant. West-northwest lineations in transition-zone rocks can be recognized along the Ruby Mountains and East Humboldt Range for ⁶⁰over 100 km across the strike of the lineation (fig. 2a). Similar fabric and lineation with virtually the same strike occurs in transition-zone rocks in the northern Snake Range and Kern Mountains 150 km to the southeast (fig. 1; Nelson, 1969).

Thus the orientation of extending flow may have been constant over a large region of northeastern Nevada.

Gravitational flattening coupled with horizontal tectonic transport also characterizes the Raft River-Grouse Creek Mountain metamorphic terrane 200 km to the northeast (fig. 1; Compton and others, 1977). There, deformation decreased downward into Precambrian basement, in contrast to the Ruby Mountains terrane where migmatite and infrastructural mobility increased downward.

The regional distribution of Phanerozoic metamorphic rocks in the Great Basin is patchy; the Ruby Mountains is the largest exposure of migmatite (Misch and Hazzard, 1962; Armstrong and Hansen, 1966; Compton and others, 1977). Does this mean that the Ruby Mountains is an isolated thermal high, or could it be representative of a much broader infrastructure at depth like that now exposed in the Omineca crystalline terrane of British Columbia (Wheeler, 1970)? One clue may come through studies in progress by Anita Harris of regional distribution of low-grade metamorphism as indicated by conodont color alteration (Epstein and others, 1977). Other clues may come through mapping of regional metamorphic terranes along strike in Idaho and in southeast California and Arizona. Resolution of the timing of metamorphism is of course critical.

The age of metamorphism and infrastructure development in the Ruby Mountains is unsettled, despite extensive geochronologic study (Kistler and Willden, 1969; Willden and

Kistler, 1969; Kistler and O'Neill, 1975; Snoke, 1975, in press--this volume). Tertiary potassium-argon ages have been interpreted to be reset, not original (Armstrong and Hansen, 1966; Thorman, 1966; Mauger and others, 1968; Kistler and O'Neill, 1975). Strontium and lead isotopic data are not yet published, and interpretation of them is complicated by apparent mixing. Metamorphism must be younger than the Devonian strata involved, and probably younger than the youngest (Triassic) conformable deposits of the Cordilleran miogeocline. A middle Jurassic whole-rock Rb-Sr age assigned by Willden and Kistler (1969) for pegmatitic granite may date the main stage of intrusion and metamorphism. Westward overturning of the Soldier Creek nappe, and of higher folds to the north (Snoke, 1974), possibly are related to westward-directed folds and thrusts 20-40 km to the west in the Carlin-Pinon Range area which Smith and Ketner (1977) date as latest Jurassic or Early Cretaceous. Table 3 summarizes the sequence of events as known from the Ruby Mountains. Continuing geochronologic study by Kistler and by Snoke and coworkers may eventually resolve the age of the metamorphic complex. The age is key to how the complex is related to other metamorphic complexes, and how or whether it is related to Sevier thrusting, basin-and-range extension, or other tectonic events.

Table 1. Stratigraphic units

Rock	Metamorphic minerals ^{1/}	Tectonic thickness	Inferred age
<u>Marble of Snell Creek.</u> Banded gray and white limestone marble with a few dolomitic laminae. Possible crinoid stems. Tentatively correlated with Devonian Guilmette Formation.	Calcite, dolomite	70 m	Devonian
<u>Dolomite.</u> Massive white dolomite marble.	Dolomite, tremolite	50 to 150 m	Devonian Silurian and Ordovician
<u>Eureka Quartzite.</u> White meta-quartzite.	Quartz, diopside	0 to 70 m	Ordovician
<u>Marble of Verdi Peak.</u> Impure limestone marble, calc-silicate rock, some schist and gneiss. Brown dolomite marble in lower part. Base commonly graphitic.	Calcite, diopside, phlogopite, plagioclase, scapolite actinolite, idocrase, garnet, sphene, K-feldspar, epidote, forsterite, in calc-silicate rocks. Plagioclase, hornblende, biotite, quartz, muscovite, sillimanite in schists	50 to 3000 m	Ordovician and Cambrian
<u>Prospect Mountain Quartzite</u> (unrestricted). Brown foliated meta-quartzite, feldspathic and micaceous. Minor schist and calc-silicate.	Quartz, biotite, muscovite, K-feldspar, plagioclase, sillimanite	50 to 1000 m	Cambrian and Precambrian Z

^{1/} Coexisting mineral assemblages are listed in Howard (1966).

Table 2. Characteristics of granitic rocks
in the northern Ruby Mountains

Pegmatite granite. Leucocratic. Varies in composition from granite to trondhjemite. Biotite, muscovite, some garnet, sillimanite. By far the most voluminous granitic rock in the complex. Sills, dikes, and irregular bodies on scales from lit par lit to more than 200 m thick. Percentage increases downward, reaching 100 percent in some deep parts of the complex. Varies from synkinematic (gneiss) to late kinematic (dikes). Metasedimentary relics intermixed with the pegmatitic granite show ghost stratigraphy. Pegmatitic granite south of the study area is assigned a Jurassic age by Willden and Kistler (1969).

Adamellite gneiss of Thorp Creek. Muscovite-biotite-garnet gneiss. Early synkinematic. Forms a sill-like body averaging 60 m thick in the core and upper limb of the Lamoille Canyon nappe.

Granodiorite gneiss of Seitz Canyon. Biotite granodiorite gneiss. Synkinematic. Forms core of Lamoille Canyon nappe. Contains metasedimentary relics showing a ghost stratigraphy.

Biotite adamellite. Forms irregular bodies of mylonite gneiss in the transition zone (early synkinematic), foliated sill-like to irregular bodies in sillimanite zone (late synkinematic) and dikes (post kinematic).

Two-mica granite and adamellite. Some contains garnet. Small

irregular bodies which in the sillimanite zone may postdate most pegmatitic granite.

Biotite granite mylonite gneiss in the transition zone (early synkinematic) may be related.

Table 3. Summary of geologic history. Time scale not constant.

PALEOZOIC	MESOZOIC(?)	CENOZOIC
<u>Miogeoclinal sedimentation</u> (Late Precambrian through at least Devonian---region- ally to Triassic)	<u>Metamorphism</u> <u>Blastomylonitic thinning</u> <u>Nappe folding</u> <u>2-mica adamellite</u> <u>Granodiorite</u> <u>Westward thrusting</u> <u>Pegmatitic granite</u>	<u>Uplift and cooling</u> (Oligocene and Miocene ²) <u>Unroofing</u> (late Miocene ³) <u>Basalt dikes</u> (Miocene ⁴) <u>Detachment faulting</u> (Neogene ⁴) <u>Block faulting</u> (Miocene ³ to Holocene) <u>Granodiorite pluton</u> (Oligocene ^{5,1})
	<u>Thrusting</u> <u>Jurassic?</u> ¹	
	<u>Biotite adamellite</u> <u>2-mica granite (Cretaceous?)</u> ¹	

¹ Willden and Kistler, 1969; Kistler, pers. comm., 1975

² Kistler and O'Neil, 1975

³ Smith and Ketner, 1977; Sharp, 1939

⁴ Snoke, in press (this volume)

⁵ Willden and others, 1967

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Miogeoclinal sedimentation (Late Precambrian through at least Devonian---region- ally to Triassic)	Metamorphism	Uplift and cooling (Oligocene and Miocene ²)
	Blastomylonitic thinning	
	Nappe folding	Unroofing (late Miocene ³)
	2-mica adamellite	
	Granodiorite	Basalt dikes (Miocene ⁴)
Westward thrusting	Pegmatitic granite	Detachment faulting (Neogene ⁴)
	Biotite adamellite	Block faulting (Miocene ³ to Holocene)
	2-mica granite (Cretaceous? ¹)	Granodiorite pluton (Oligocene ^{5,1})

1 Willden and Kistler, 1969; Kistler, pers. comm., 1975

2 Kistler and O'Neil, 1975

3 Smith and Ketner, 1977; Sharp, 1939

4 Snook, in press (this volume)

5 Willden and others, 1967

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ILLUSTRATIONS

Figure 1. Location of major metamorphic complexes in Nevada and Utah: Ruby Mountains (RM), Raft River Range (RR) and Snake Range ^(SR) terranes.

Figure 2. Sketch map of the Ruby Mountains, East Humboldt Range, and Wood Hills (from Thorman, 1970; Snelson, 1957; Stewart and Carlson, 1977; and Howard and others, in press). The Wood Hills expose metasedimentary rocks. In the Ruby Mountains and East Humboldt Range the metamorphic complex consists of a mylonitic transition zone with WNW lineation, and an underlying migmatitic core in which folds and lineations are variably oriented. Numbered anticlines are (1) Lamoille Canyon nappe, (2) King Peak nappe, (3) Hidden Lakes uplift, and (4) Soldier Creek nappe. Lower and middle Paleozoic strata in the southern Ruby Mountains are largely separated from the metamorphic complex by granitic plutons of Tertiary, Jurassic(?) and Cretaceous (?) ages. Klippen of upper Paleozoic strata overlie the complex. Cenozoic sediments (unpatterned) flank the ranges.

Figure 3. Generalized geologic map of part of the northern Ruby Mountains (located in fig. 2). Granitic rocks are abundant but are shown only where metasedimentary relics are lacking. A thrust fault (Ogilvie thrust) exposed in the Lamoille Canyon nappe predates

metamorphism and folding.

Figure 4. Cross sections. Locations are indicated on figure 3.

Figure 5. Cartooned oblique view of relations among large folds in the northern two-thirds of the area shown in figure 3. Surfaces shown are tops of Prospect Mountain Quartzite (lined) and Eureka Quartzite (dotted). Post-metamorphic faulting of the Hidden Lakes uplift and Soldier Creek nappe has been restored.

Figure 6. Comparison of Prospect Mountain Quartzite (a) in transition zone, where rock is tectonically thinned, flaggy, and blastomylonitic, and (b) in metamorphic core, where rock is higher grade, coarsely crystalline, annealed, and not greatly thinned. *migmatite*

Figure 7. Character of streaky WNW-trending lineation of the transition zone, here seen on the foliation surface of a granite gneiss.

Figure 8. The streaky WNW lineation of the transition zone parallels the slip direction determined from vergence separation arcs of folds. (a) Azimuthal frequency of overlaps of fold separation arcs. (b) Azimuthal frequency of streaky lineation.

Figure 9. A possible model of infrastructure development, cartooned by east-west cross sections. (A) Diapirs form as migmatite front rises. (B) Mobile infrastructure presses bouyantly against suprastructure, causing outward flow and attenuation of

nappes. (C) Cooling transforms infrastructure into new rigid basement, against which detachment faults bottom.

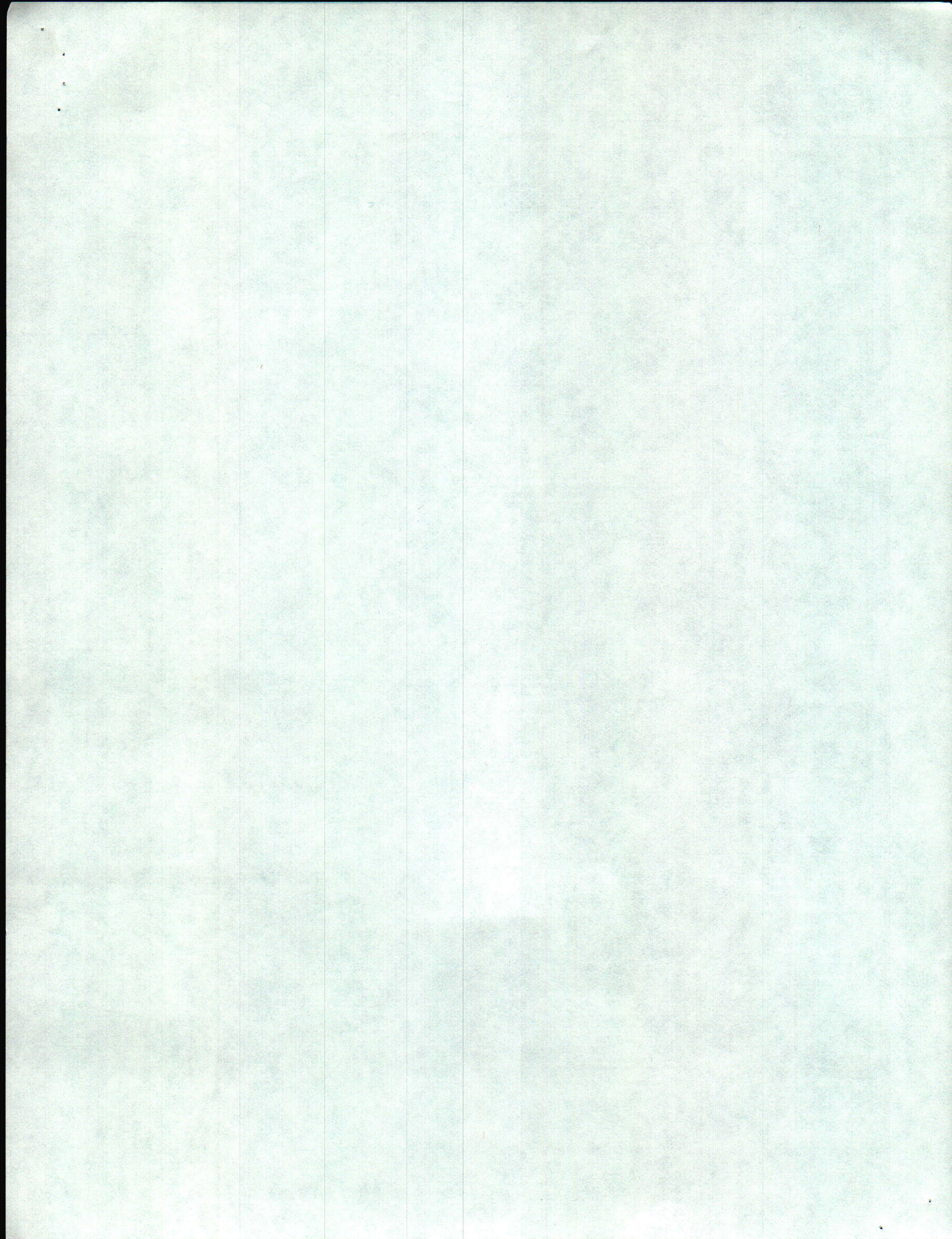


Fig 1

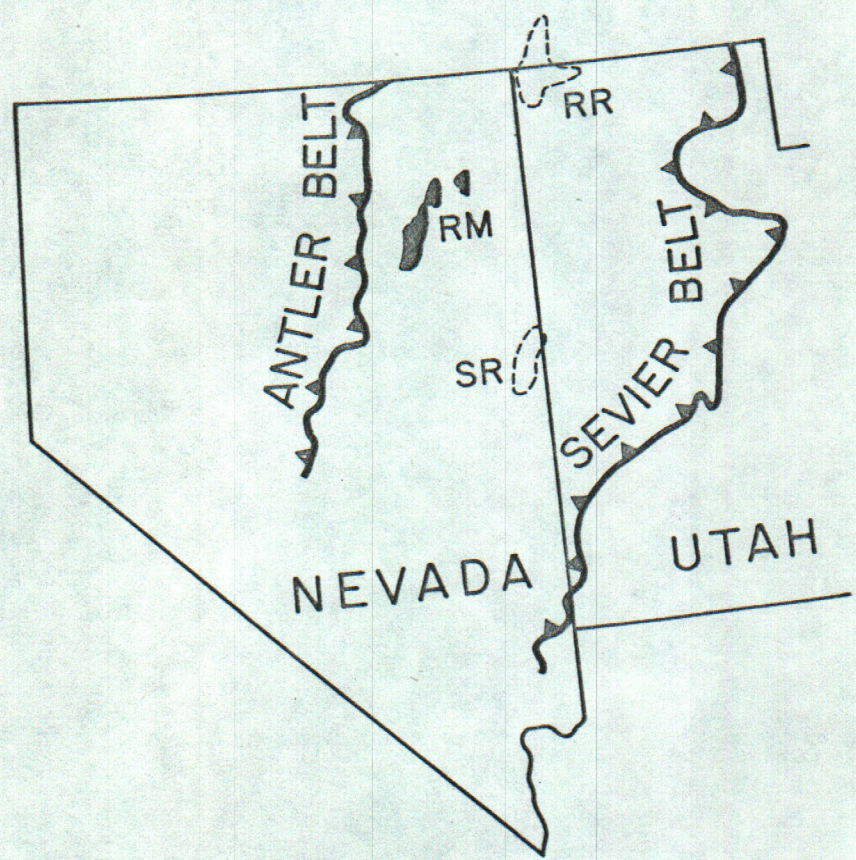


Fig 1

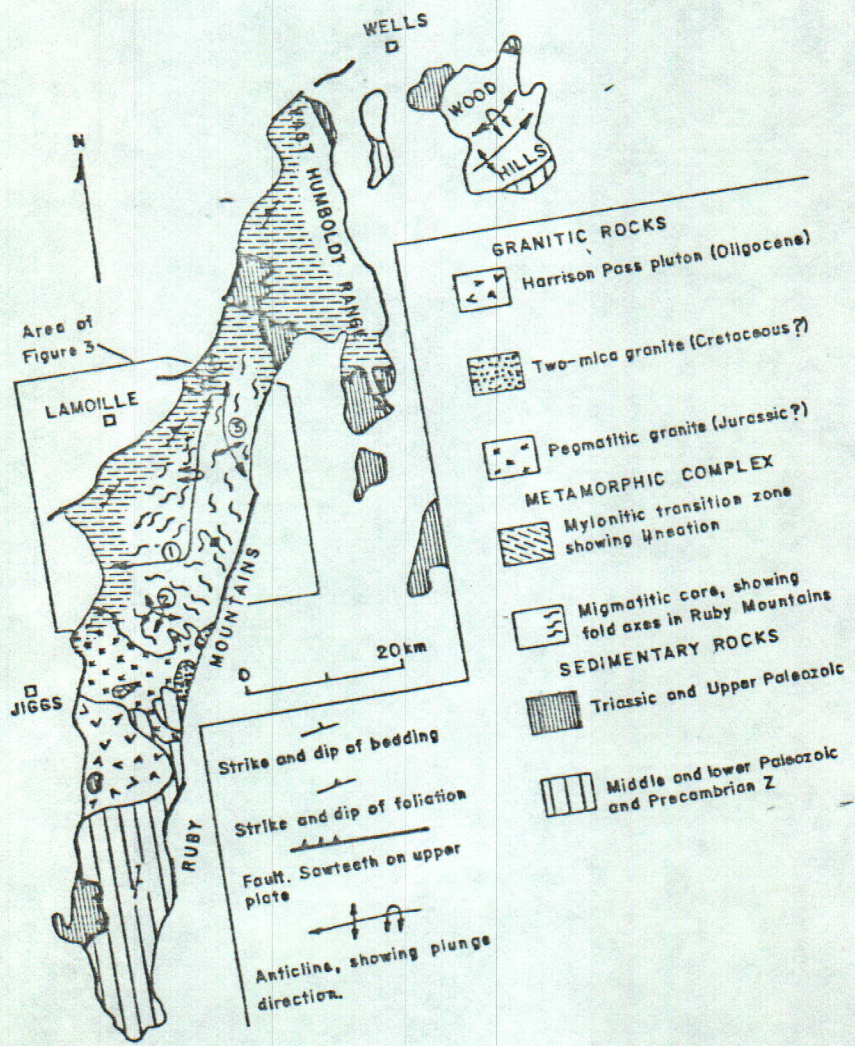
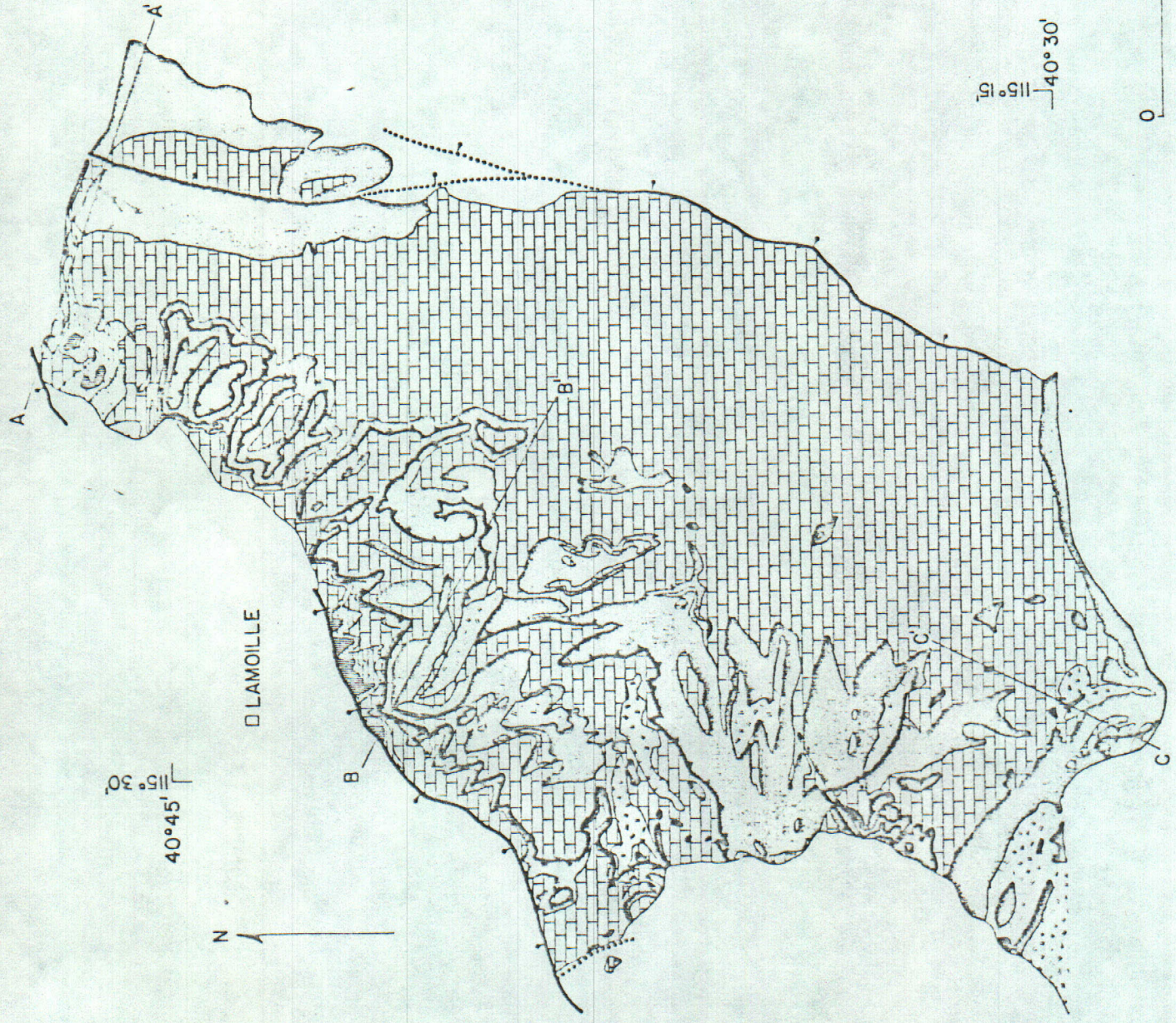


Fig. 1



EXPLANATION

- Sediments (Cenozoic)
- Granitic rocks (Mesozoic; shown where no metasedimentary relics)
- Limestone (Pennsylvanian)
- Marble (Devonian)
- Dolomite (Devonian to Ordovician)
- Eureka Quartzite (Ordovician)
- Marble (Ordovician and Cambrian) and granitic rocks (Mesozoic)
- Prospect Mountain Quartzite (Cambrian and Precambrian Z) and granitic rocks (Mesozoic)

Fault - dotted where concealed; ball on downthrown side; sawteeth on upper plate of thrust

A—A' Line of section shown in figure 4

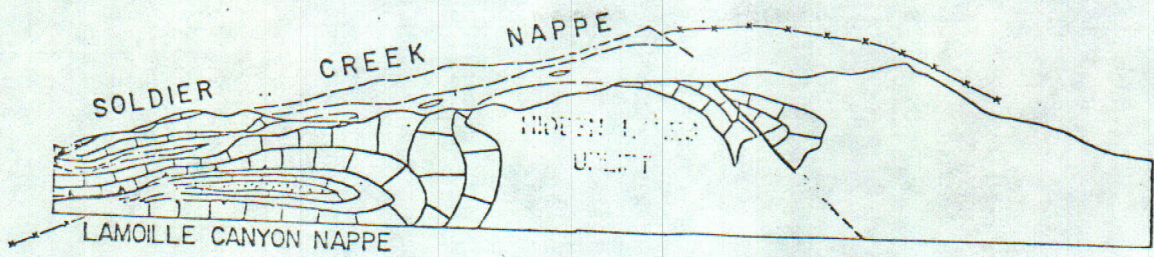
0 5 10 Km

115° 15' 40° 30'

4

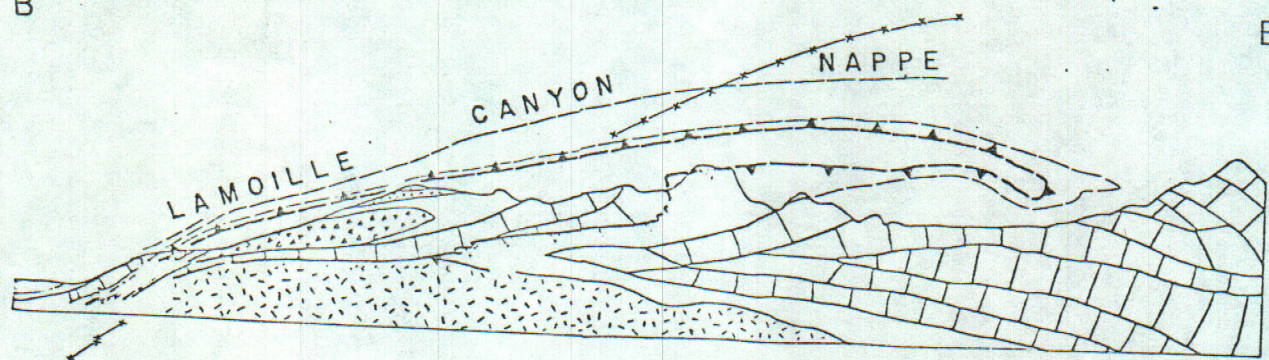
A

A'



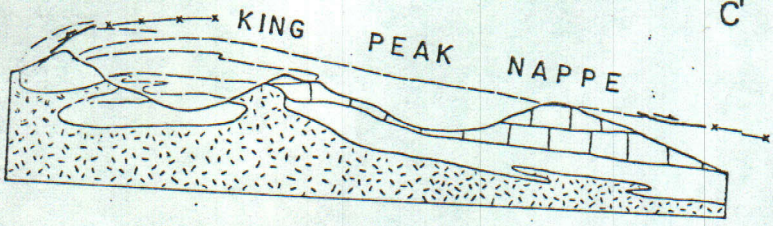
B

B'












C

C'



EXPLANATION

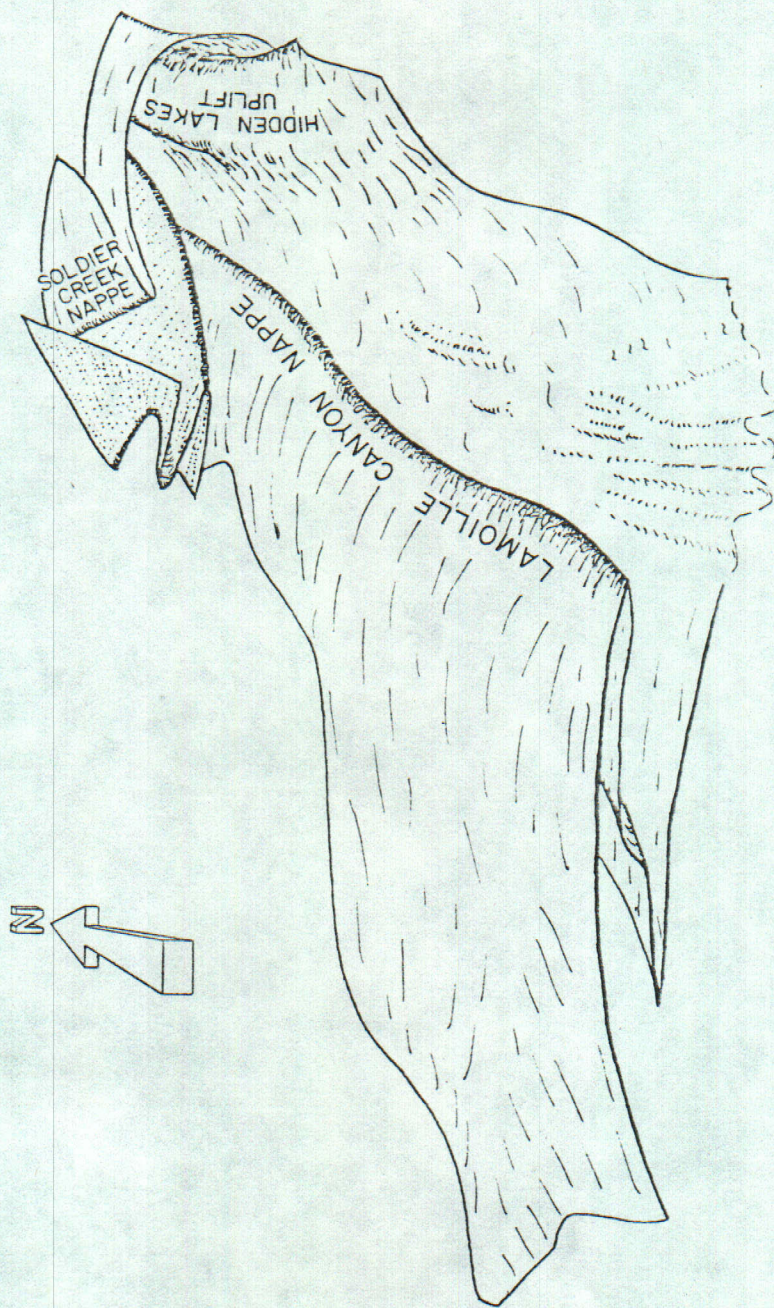
-  Two-mica granite and adamellite
-  Pegmatitic granite
-  Granodiorite gneiss
-  Adamellite gneiss
-  Marble of Snell Creek (Devonian)
-  Dolomite and Eureka Quartzite (Devonian to Ordovician)
-  Marble of Verdi Peak (Ordovician and Cambrian) and granitic rocks (Mesozoic)
-  Brown dolomite (Cambrian) and granitic rocks (Mesozoic)
-  Prospect Mountain Quartzite (Cambrian and Precambrian Z)

Premetamorphic thrust fault

Approximate base of transition zone

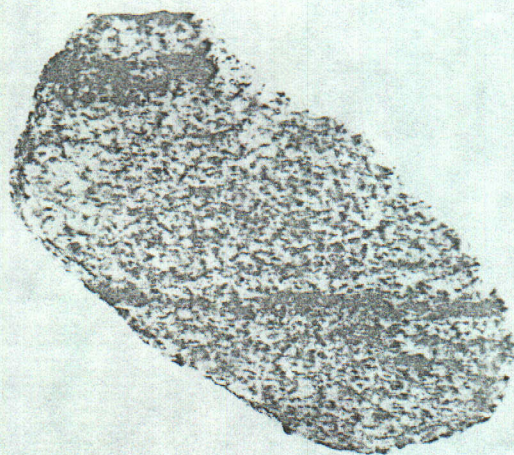
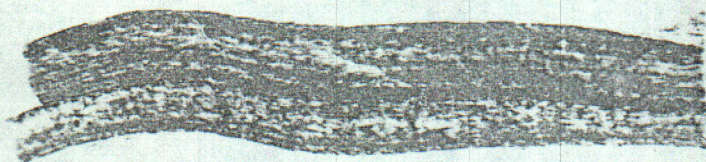
0 2km

Fig 5



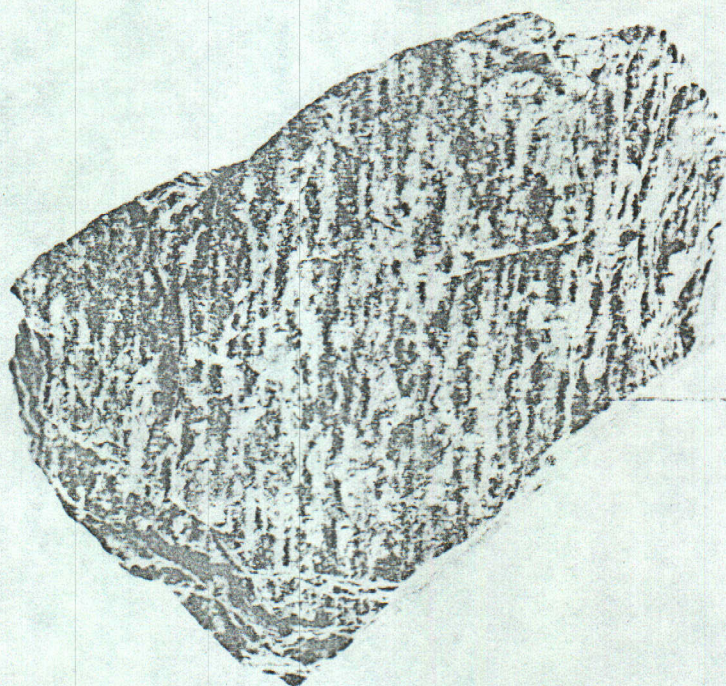
a

b



5 CM

7



5 CM

Fig. 8

Fig. 8

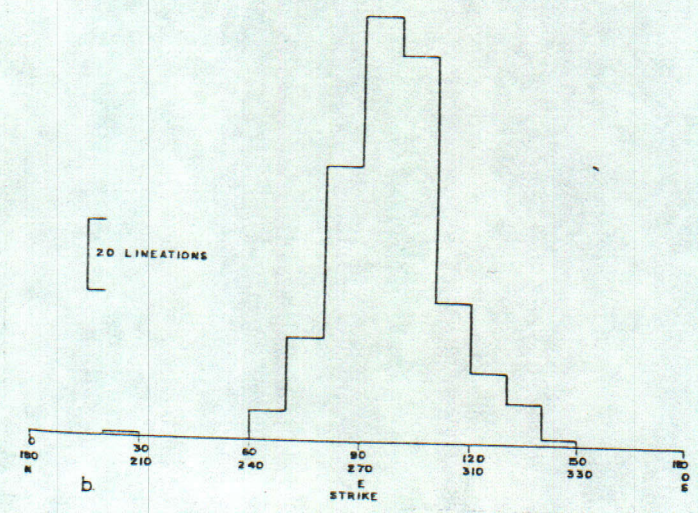
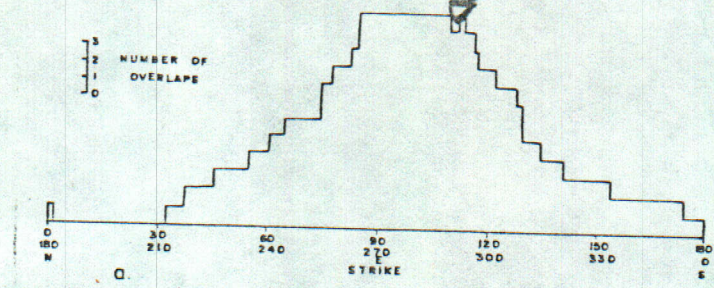


Fig. 7

