Guidebook to the Proterozoic Accretionary Terrane of the Central Colorado Front Range

First Edition

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Sue Hirschfeld

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ABSTRACT

The Central Front Range of the Colorado Rockies is dominated by an early Proterozoic (ca. 1.8-1.7 Ga) metamorphosed volcanic and sedimentary sequence. In terms of plate tectonics, these rocks are interpreted as island arc, back-arc, and sedimentary basin-fill units formed during the accretion of Colorado onto the North American Craton. Despite good exposures, which we will be able to observe throughout the field trip, and their proximity to a large metropolitan area, these rocks are still not well understood. New research is underway to better understand accretionary processes in this region. The boundaries of the Central Front Range arc sequence are currently undefined. On the east and west, the sequence is terminated by Laramide-age faulting. The Pike's Peak Batholith obscures the southern boundary, and the northern boundary is problematic.

The main units present in the Central Front Range arc sequence are amphibolites, felsic gneisses, calc-silicate gneisses, mica schists and gneisses, iron formations, meta-greywackes, quartzites, and meta-conglomerates. These units as a whole are often called the "Idaho Springs Formation", but that is not a valid formation name. The degree of metamorphism is generally upper amphibolite grade, high T – low P. Anatectic conditions were reached in the felsic gneisses and mica schists over much of the area. This field trip examines these units in an area of slightly lower grade, where the character of the rocks is not masked by complications of anatectic melting.

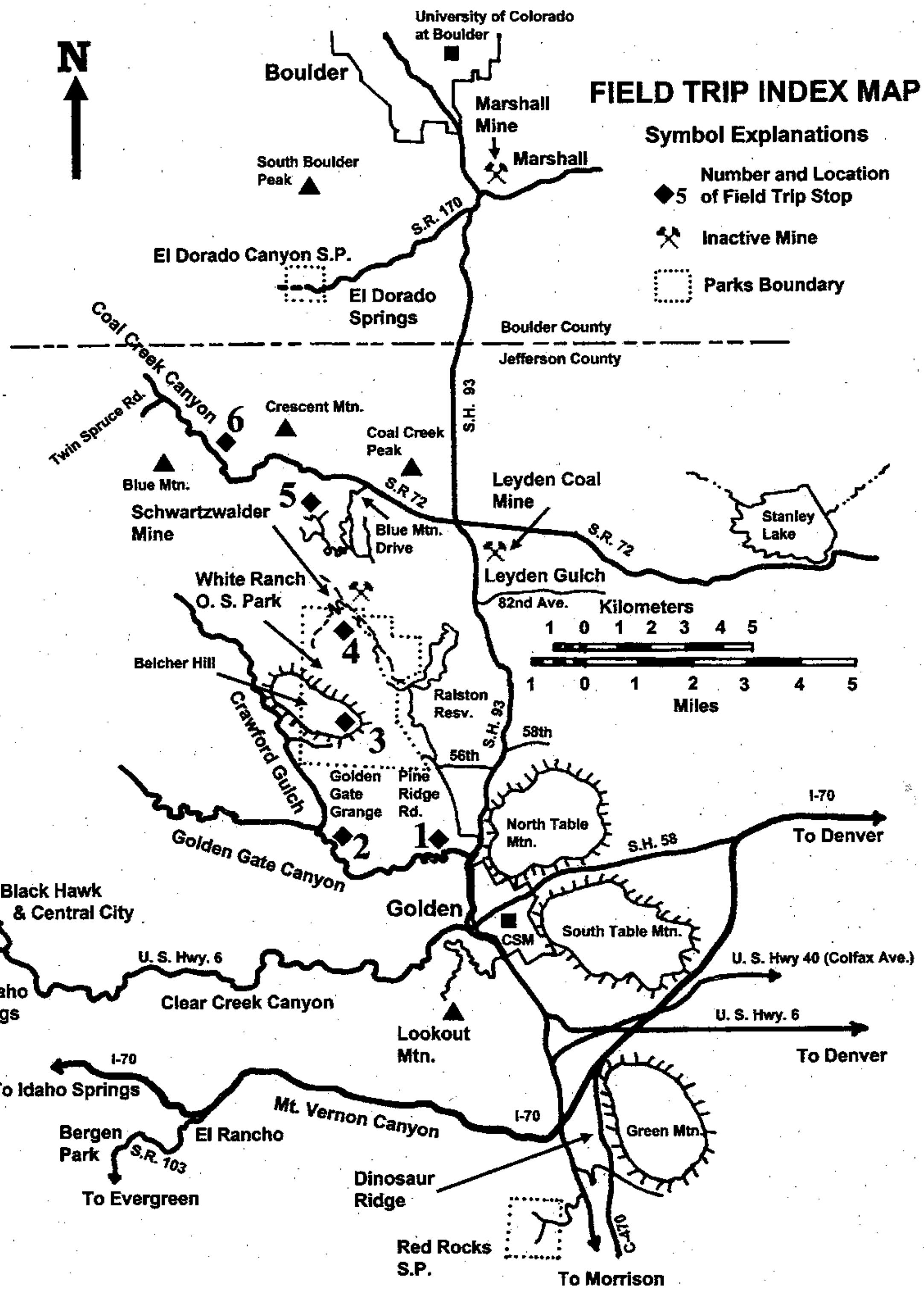

Figure 1. Field trip index map with planned stops and local geographic features.

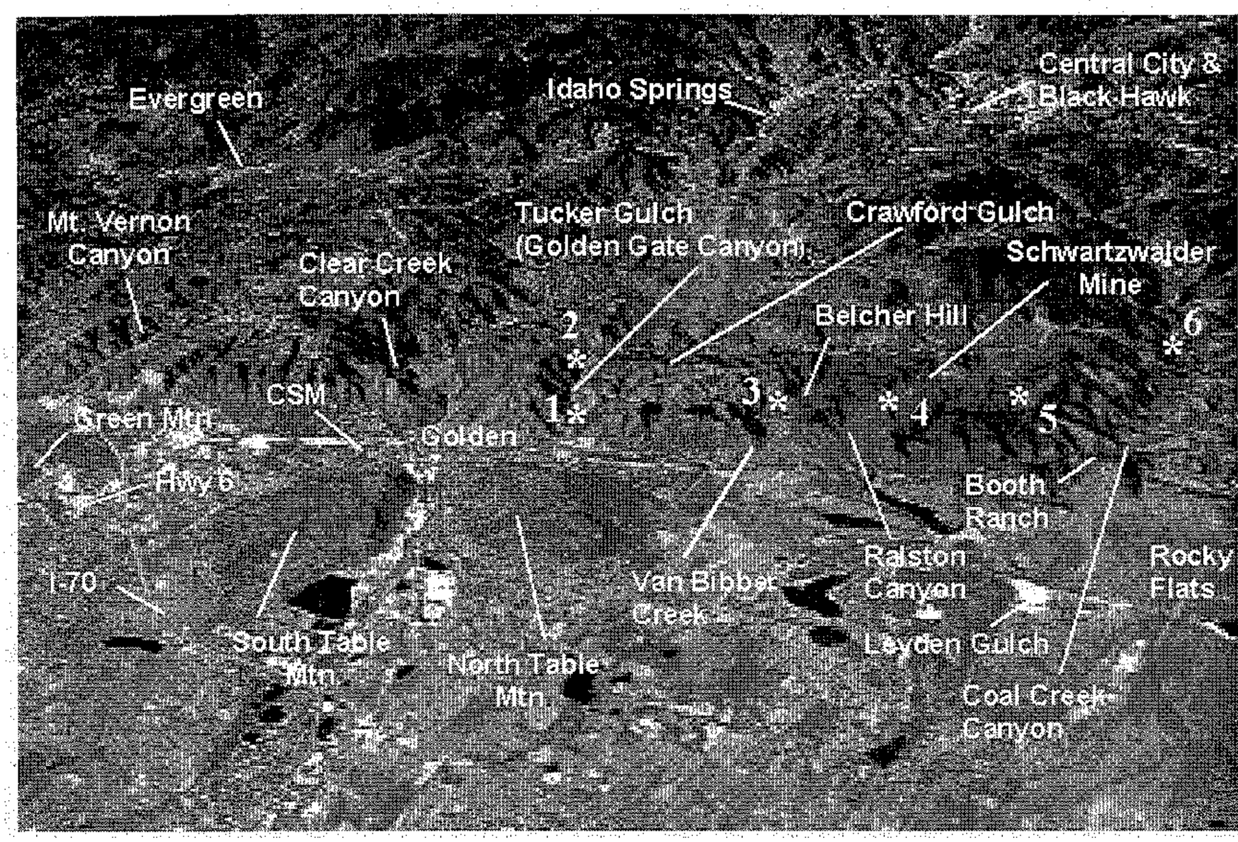

Figure 2. Oblique thirty-meter 3-D satellite image of field trip area with stops. View is to west-southwest into the Central Front Range.

INTRODUCTION

*The Precambrian schists and gneisses of the Colorado Front Range have often been called the "**Idaho Springs Formation**". This is not a valid formation name, but it remains in popular use as a way to refer to this sequence of lithological units.*

The history of geologic study of the Colorado Front Range Precambrian rocks is a fascinating one, begun by the Hayden Survey in 1874 (Marvine, 1874). I (Lisa) included a detailed review of the various workers and their ideas in my Master's thesis (Finiol, 1992). What I find most interesting is that the early scientists did not merely lump the metamorphic rocks into "basement", but did break them into units that even today still convey meaning to those of us who work in the area, despite out-of-date interpretations. The geologic quadrangle mapping of the area in the 1950-60's by U.S. Geological Survey workers (e.g., Sheridan et al, 1967; Wells et al, 1964) gave us excellent field maps and descriptions of the units, and a good base for further interpretive study today.

In the 1980's, new ideas were brought forward by geologists to interpret regional Precambrian geology of the western U.S. in terms of modern plate tectonics theory. As is usual in science, the more we learn, the more questions are raised. The 1980-90's findings that accretionary tectonics were responsible for formation of the region today give way to a desire to better define details of how this occurred.

Despite the proximity to a large metropolitan area, the metamorphic rocks in the central Front Range have not been extensively studied or seriously visited by many geologists. Our objective on this field trip is to introduce more geologists to these fascinating rocks and how they fit into the new story of the accretion of the North American craton. Further, we wish to share our plans on how we can improve our understanding of the accretionary process through our current study of the Coal Creek Quartzite, and generate discussion and ideas for future investigation.

TECTONICS AND GEOLOGY

Proterozoic rocks of Colorado represent addition of the Colorado Province to the Wyoming craton in a 1.8-1.7 Ga accretionary event (Condie, 1986). Current studies (e.g., CD-ROM Project) are endeavoring to determine details concerning how and when the individual components of the terrane were formed, location of boundaries of accreted arc sequences (geologic elements), and thus gain a better understanding of the tectonic processes involved (figure 3). The metamorphosed volcanic and sedimentary arc sequence of the central Front Range is one component of the accreted terrane in the Colorado Province.

The boundaries of the central Front Range arc sequence are currently undefined. The eastern and western extents are terminated by Laramide-age faulting. To the south, a boundary separating the sequence from that of the Wet Mountains must exist, but has yet to be established. This boundary may be obscured by the Pikes Peak Batholith. The northern boundary is also difficult to determine as we have not yet recognized any clear lithological or geochemical breaks. A closer look at the units of the Front Range is shown in figure 4.

The arc sequence of the central Front Range has characteristics in common with others of the Colorado Province, but still differs in some respects. Metamorphic grade of the central Front Range is upper amphibolite. This is higher than many other Colorado sequences, such as the Gunnison Greenstone Belt at greenschist grade. The protolith of metasedimentary rocks in the central Front Range was pelitic shale, and quartzitic sandstones and conglomerates. Elsewhere in Colorado these may be greywackes, the more common sediment type found in similar sequences in the Gunnison area.

CENTRAL FRONT RANGE ARC SEQUENCE

The main units present in the central Front Range arc sequence are metamorphosed volcanic and sedimentary units, consisting of mica schists and gneisses, iron formations, calc-silicate gneisses, hornblende gneisses, amphibolite gneisses, felsic gneisses and quartzites (all part of a package unofficially called the "Idaho Springs Formation"), with plutons of Boulder Creek (~1700 Ma), Silver Plume (~1400 Ma), and Pikes Peak (~1000 Ma) ages. Isotopic data restrict the age of the gneisses to between 1700-1900 Ma. The geology of the area we will visit on the field trip is shown in figure 5, where all these units are present at slightly lower P-T conditions than elsewhere in the central Front Range. The units are interpreted as follows (Finiol, 1992):

Interlayered Gneiss: Interlayered metamorphosed intermediate felsic and mafic volcanics, volcaniclastics, and related intrusives, representing a low-K tholeiitic immature bimodal volcanic arc assemblage related to subduction occurring south of the Wyoming craton.

Hornblende Gneiss: Metamorphosed submarine volcanic sequence with related carbonates and cherts, representing backarc generation of submarine tholeiitic basalt flows, with interlayered carbonates, cherts, greywackes, and other minor sediments which accumulated during periods of volcanic quiescence.

Transition Zone: Metamorphosed laterally variable package of chert, sediment, stratabound sulfides, and iron formations, representing exhalative-related deposits related to declining volcanic activity. The cherts and iron formations represent the more distal or lower temperature portions of hydrothermal vent deposits, and the sulfides nearer to the higher temperature vents.

Mica Schist: Metamorphosed pelitic shales containing sandy channels and cherty carbonate pods, representing basin sedimentation in a continental margin arc.

Coal Creek Quartzite: Metamorphosed sandstone with intercalated conglomerate and shale layers.

This arc sequence then collided with the growing Wyoming craton to the north, resulting in the deformation and metamorphism of the package. Syntectonic emplacement of the Boulder Creek age plutons occurred as the area became part of the magmatic arc.

METAMORPHISM

The metamorphic rocks of the central Front Range are of upper amphibolite grade: a high T – low P metamorphism, where anatectic melting reactions were reached. This indicates that heat added to the crust from intrusive bodies, rather than deep burial, was more important to the regional metamorphism.

One small area in the vicinity of White Ranch Park, Jefferson County, is of slightly lower metamorphic grade. P-T conditions for anatectic melting were not reached, and sillimanite-muscovite and/or andalusite-muscovite was stable. Indicated pressures and temperatures of metamorphism are 525° - 625° C at 3 - 3.75 kb (approximately 10-12 km depth). (Finiol, 1992)

Outside of the White Ranch Park area, anatectic migmatites are commonly developed and appear to be compositionally controlled. In the mafic and calc-silicate units, P-T conditions for anatectic melting were not reached, and the migmatites present are produced by injection, metasomatism, or subsolidus processes, not of anatectic origin. However, P-T conditions for anatectic melting are lower for rocks of pelitic and felsic compositions, and anatectic migmatites are common in the pelitic and felsic volcanic units. Degree of migmatization changes across the area. Though not a simple relationship, there is a general increase of metamorphic grade towards the Mt. Evans pluton.

NEW DIRECTIONS

We have learned much over the last 20 years about the how the Colorado Province was formed, but we still have much to discover. There is a need to define strategies for determination of arc sequence boundaries, more accurately date the sequences, and determine more about the tectonic processes that formed the Colorado Province.

Through continued study of the central Front Range, we can work to define and understand the role this sequence plays in the larger picture. New work is underway to re-examine the Coal

Creek Quartzite (Fisher & Fisher, 2004), looking past the metamorphic overprint with attention to sedimentalogic and stratigraphic detail. This may help to characterize basin extent, depositional environment, tectonic environment, etc., and may aid in defining arc sequence boundaries.

UNIT DESCRIPTIONS

Interlayered Mafic and Felsic Gneiss Unit

The mafic gneiss and felsic gneisses are interlayered, with the mafic gneiss more prevalent in the lower layers and to the north, and the felsic gneiss more prevalent in the upper layers and to the south. The mafic gneiss is a fine to medium grained, foliated amphibolite, composed of plagioclase and hornblende with possible minor biotite, sphene, clinopyroxene, and microcline (figures 6,8).

The felsic gneiss is a very fine to fine grained, foliated metamorphosed quartz latite to dacite, composed of plagioclase, quartz, and microcline with possible minor biotite, hornblende, or muscovite (figures 7,8). Some layers contain relict phenocrysts of microcline. Both mafic and felsic gneisses contain thin layers of calc-silicates, which are composed of plagioclase, quartz, and epidote with possible calcite, hornblende, and other accessory minerals and indicate submarine deposition as impure carbonates (figure 7).

Hornblendites are intrusive mafic to ultramafic bodies in the interlayered gneiss. They are medium grained, foliated amphibolites, composed of hornblende, some with relict phenocrysts which are now tremolite (figures 6,8).

The transition to the next unit is a zone ~1-15 m thick of variable composition, gradational, often containing garnet and sillimanite. In places, this is represented by quartzites, marbles, metaconglomerates, or schists.

On the field trip, we will see this unit on the southern end of the area, near the mouth of Golden Gate Canyon. Here it is represented by predominantly felsic gneiss. It is a little coarser here than on the north. There are several calc-silicate layers (showing some boudinage), indicating that the felsic volcanics were submarine. There are some layers of garnet- and sillimanite- rich gneiss marking the gradational transition between the felsic gneiss and the overlying hornblende gneiss. The road up the canyon almost follows the contact between the felsic gneiss and the hornblende gneiss, and crosses the contact several times. Along the road, the generally pink outcrops are the felsic gneiss, and the dark grey-black outcrops are the hornblende gneiss. As we drive up Golden Gate Canyon, there are several outcrops of the felsic gneiss, showing color variations in compositional layering. The pinker layers contain more microcline, the grayer layers more plagioclase. Most layers are 0.5 – 10 m thick.

If time and weather permit, we will visit this unit on the north end of the area, near Coal Creek Canyon at the former Booth Ranch property. Here it is represented by predominantly mafic gneiss. Felsic gneiss units here are generally finer than in the south. Outcrops of hornblendite have "eyes" of relict phenocrysts.

Hornblende Gneiss Unit

The hornblende gneiss unit is complexly interlayered amphibolite, calc-silicate, and schist. Amphibolite predominates in the lower part of the unit, and grades upwards into calc-silicates plus or minus schists. The calc-silicates are more prevalent to the north, and the more clastic schist layers to the south.

The hornblende gneiss is a moderately to strongly foliated, fine-grained amphibolite, composed of hornblende and plagioclase with possible minor clinopyroxene (figure 9,11). Layers can be massive or finely interlayered with calc-silicate. Some pillow and other volcanic textures are preserved (figure 10).

Calc-silicate layers contain calcite, plagioclase, hornblende, clinopyroxene, quartz, and epidote, plus accessory minerals. They range from impure marbles to metacherts to true calc-silicate compositions (figures 9,11). In some places and to the south, there is a more clastic contribution to the layer, which produces schists of variable composition (figures 9,11). The transition to the next unit is gradational.

On the field trip we will see the southern part of this unit at the mouth of Golden Gate Canyon, at the contact with the felsic gneiss. There are several thick layers of amphibolite, with a large almost Y-shaped pegmatite just around the curve in the outcrop to the west. As we drive up the canyon, the dark outcrops are the hornblende gneiss. We will pass a small, old log cabin next to an old uranium prospect on the northeast side of the road. At this point, there is a thick, black massive amphibolite layer next to a lighter grey unit of quartz-rich metasediment. We will see these units at the parking lot of the Golden Gate Grange, Stop 2. Also at this stop is a large Silver Plume pegmatite, with quartz, microcline, plagioclase, and muscovite. In several places in the area, the Silver Plume pegmatites also contain tourmaline.

We will see the northern part of the hornblende gneiss (Stop 4) near the gate of the Schwartzwalder Mine, where it is a thick amphibolite, and on the Schwartzwalder property, where we will observe relict volcanic features, such as pillows, vesicles, flow structure, etc. in the amphibolite, and also calc-silicate gneisses.

Transition Zone

The transition zone is 3-100 m thick and is laterally variable composition. In most places, the unit is a thin, 3-20 m metacherts (figure 18). In other places, there is a clastic contribution to the unit, producing quartz gneiss. In the area of the Schwartzwalder uranium mine, the unit thickens to 100 m and develops into an iron formation (figures 12,13), with all 4 facies of iron formation present. Massive sulfide deposits occur locally. Much of the Transition Zone is interpreted as exhalative sea-floor deposits of chert, iron-rich chert, and massive sulfide deposits in the waning stages of volcanic activity. Locally, there are influxes of clastic sediment, which alter the character of the rocks.

The oxide facies of the iron formation exhibits sedimentary structures, such as cross bedding and climbing ripples, etc. Garnet and magnetite grains define original bedding layers rich in iron. The transition to the next unit is gradational.

On the field trip, we will first see a part of the iron formation of this unit in the canyon cut by Ralston Creek. At this point we are just outside the Schwartzwalder Uranium Mine property owned by Cotter Corp., and are in the protected area of White Ranch Park of Jefferson County Open Space. There are golden eagles and other raptors nesting in the cliffs above us, and mountain lion and black bear abundant in the area. Please be respectful of their need for relative quiet and solitude, as well as cautious of their presence.

We will see more of this unit as we drive into the Schwartzwalder property, and up a very rugged 4WD road to the south side of the property. Please be aware that we have encountered very large rattlesnakes here in the past.

The main portion of the iron formation here is oxide facies. There are magnetite-rich schists, iron-rich metacherts, and magnetite-quartz-garnet schists. There are a few thin calc-silicate layers within the iron formation layers, indicating submarine deposition (figure 14). Some sulfide facies iron formation samples have been identified within the mine workings. Silicate facies iron formation occurs in a small area on the north side of the unit, and possible carbonate facies occur on the west side of the unit.

Mica Schist Unit

The mica schist is highly pelitic, composed of quartz, muscovite, biotite, and sillimanite or andalusite, plus or minus garnet or cordierite (figures 14,16). The schist varies from very quartz-rich to very andalusite-rich or sillimanite-rich (figures 15,16). The sillimanite isograd was reached throughout much of the central Front Range, with andalusite stable in the general area of White Ranch Park where porphyroblasts reach 30+ cm in length. The schist exhibits sedimentary features such as trough cross bedding and climbing ripples, and contains lenses and channels of coarser sand-sized material, meta-conglomerates, or calc-silicates. The various lithologies of the schist represent a varied sediment fill of pelitic shales to quartz-rich siltstones in the backarc basin.

The transition to the Coal Creek Quartzite is obscured within the Idaho Springs – Ralston Shear Zone. The deformation within the shear zone is inconsistent, with areas that are relatively undeformed. Within these areas, the transition between the schist and the quartzite is gradational. The shear zone is interpreted as a sheared anticline.

On the field trip, we will see this unit in White Ranch Park. A short walk from the parking lot takes us to an andalusite-rich outcrop of schist, where porphyroblasts of andalusite reach more than 30 cm in length. This layer, when walked out across the area, exhibits various sizes of andalusites and crosses from the andalusite into the sillimanite zone, where sillimanite occurs in large ovoid masses. On the drive between the Golden Gate Grange and White Ranch Park, we will pass several outcrops of the schist. It is often silvery in appearance in the road cuts, especially if sunny. Many Silver Plume pegmatites will be apparent on the drive: one near Van Bibber Creek is rich in tourmaline; one near White Ranch Park is zoned. All are pink with sharp contacts.

Coal Creek Quartzite

The Coal Creek Quartzite is one of several clastic belts of similar age deposited in syntectonic basins during the accretion of Colorado onto the North American Craton. At its type locality in Coal Creek Canyon, the Coal Creek Quartzite consists of at least four quartzite units (A, B, C, and D in ascending order) separated by three major schist units (Wells, 1967). Units A and B are generally white to light gray and pink, fine-grained to conglomeratic, with layered hematite. Relict sedimentary structures are readily apparent in these units (figure 17). Unit C is gray with only occasional pink and white layers. It is generally much more fine-grained and massive in appearance than Units A and B, and bedding is often inconspicuous. Unit D, the upper most unit, is white to pink, generally fine-grained, with abundant lenses of conglomerate, some of which are very arkosic. The separating schist units are in gradational contact with the quartzites. Thickness of the quartzite varies over the main exposure in the Coal Creek Syncline, however Wells (1967) suggests a total thickness upwards of 10000 feet (~3000 meters). The units thin both southward and northward from the axis of the syncline. The total extent of the Coal Creek is not clear. George and Crawford (1909) reported a Coal Creek-like quartzite present in the Arapahoe Peaks area (now in the Indian Peaks Wilderness) west of Boulder that may be a time-equivalent unit.

The Coal Creek Quartzite occurs mainly within the Coal Creek Syncline, a northeast trending and plunging structure that extends into Eldorado Canyon to the north-northeast. This structure was interpreted by Wells (1967) and Wells, et al (1964) as being Precambrian in age and to be associated with emplacement of the Boulder Creek quartz monzanites and granodiorites. The structure probably does not reflect the configuration of the original depositional basin, but may still somewhat mark the original depo-center. Williams, et al, (2003) suggest that the Coal Creek and similar quartzites of Colorado and New Mexico were deposited in syntectonic basins developed on a stabilizing crust. They further suggest that the quartzites were deposited during continued thrust convergence in the late stages of the Yavapai orogeny. This interpretation remains somewhat problematic, and it is suggested here that the Coal Creek Quartzite may have been deposited in conditions more similar to those found during the accretion of the Man (Leo) Shield onto the West African Craton. There, similar "bands" of (mineral bearing) quartzites and quartz-pebble conglomerates accumulated in a series of extensional half-grabens associated with back-arc basins. Only further detailed structural, stratigraphic, and sedimentological field work will tell the whole story. It is hoped that this further field work will help reveal the true importance of the Coal Creek and similar units in understanding the crustal evolution of Colorado.

Recent investigations (Fisher and Fisher, 2004) of the Coal Creek suggest that the quartzites are fluvial in origin, most likely braided-stream deposits. Only the lowermost "A" unit has been studied to this point, however relict sedimentary structures preserved tell a story of the protolith. Generally, the lower unit consists of several stacked, fining-upward sequences of a few meters thickness each. Most of these units consist of a conglomeratic unit at the base, that transitions upward into small-scale trough cross bedding, then to more planar-laminar structures with accompanying decrease of grain-size. Some imbrication is apparent in the pebble conglomerates. Pebbles are generally equidimensional to ovoid to flat. Tectonic stretching of the pebbles is not apparent in this lower unit and individual grains are virtually undeformed (Wells, 1967). Little information has yet been gathered on paleocurrent directions. The intervening schist units are probably derived from pelitic shales. Thin partings of schist within the individual stacking units may suggest clay partings within the units. Well-marked layers with hematite alteration may suggest subareal exposure during deposition, although it is apparent that some remobilization of hematite has occurred. The quartzite units exhibit generally blocky fracturing, with fracture planes tending to exploit depositional bedding planes.

The Coal Creek Quartzite is in contact with the apparently younger Boulder Creek Granodiorite and quartz monzanite (Twin Spruce). These igneous units surround and broadly outline the Coal Creek Syncline, but the contacts are discordant in detail. Where the contact between the Quartzite and the igneous units can be observed, a micaceous selvage exists. This zone may range from absent to a few inches to a few tens of feet thick (Wells, 1967).

On the field trip, we will visit an outcrop of what is believed to be part of the basal most unit (Unit A of Wells, 1967, and Wells, et al, 1964) of the Coal Creek Quartzite, exposed in road cuts along the north side of Coal Creek. At this stop we will be able to observe relict sedimentary structures and a sequence of stacked, fining-upward units of a few meters thickness each. These units have been recently been interpreted as fluvial in origin; most likely braided-stream type deposits (Fisher and Fisher, 2004, in preparation). Most of the units are marked by a basal conglomeratic unit with possible scoured base. The conglomeratic units transition upward to small-scale trough-type cross bedding then to more planar-laminar like structures. Grain-size appears to decrease upward in relation to the change of sedimentary structures. Quartz pebbles are generally rounded and equidimensional to oval, although some are flat (Wells, 1967). Some indication of imbricate structures is present within the conglomerate beds. More distinct and well-developed channels, up to several 10's of meters across and with deep scouring at their base occur in equivalent units further to the northeast at Eldorado Canyon. Large-scale trough-type cross beds also occur at the Eldorado locale.

Thin-section examinations by Wells (1967) show the grains are virtually undeformed at this outcrop. However, stretched-pebble conglomerates have been observed in the upper Mica Schist in the Golden Gate Canyon-White Ranch area and stratigraphically higher units of the quartzite near the mouth of Coal Creek Canyon. The exposures in Coal Creek Canyon lie in a northeast trending synclinal structure interpreted by Wells (1967) as Precambrian in age. We will also be able to observe the Boulder Creek quartz monzanite, which apparently intrudes the Coal Creek Quartzite at this locale. Unfortunately, at the level of the roadcut, the contact between the two units is not exposed.

Phanerozoic Units

While the focus of this field trip is on Precambrian units, we would like to introduce participants, especially those unfamiliar with Front Range geology, to the Phanerozoic units that we will drive through as we proceed with our field trip stops.

Pennsylvanian Fountain Formation (ca. 300 Ma – 280 Ma) – Steeply east dipping along the eastern flank of the Central Front Range, the Fountain forms prominent "flat irons" and palisades along the Front Range escarpment. Mainly red arkosic sandstones and conglomerates of braided stream/alluvial fan origins; these sediments are derived from erosion of the Ancestral Rockies. They rest unconformably on the ca. 1.8-1.7 Ga "Idaho Springs Formation". Easily weathered interfluvial mudstones, claystones, and siltstones form valleys between the more resistant alluvial fans that form the flat irons. Well developed and notable fans and braided channel complexes occur at Red Rocks Park near Morrison, Ralston Canyon (the "Beartooth"), Coal Creek Canyon – Booth Ranch (Blue Mountain Subdivision) area south of County Road 72, and the Flat Irons between El Dorado Canyon and Boulder, as well as Garden of the Gods to the far south near Colorado Springs.

Permian Lyons Sandstone – Braided stream deposits of light gray to tan to reddish arkosic sandstones and conglomerates at base, grading to and interbedded with interfluvial aeolian deposits. Type locality is at the town of Lyons, Colorado where it is almost all aeolian in origin. Quarried for dimension stone, it is the source of the majority of stone facings on buildings of the University of Colorado at Boulder. Correlation of the Lyons in the Morrison-Golden area is problematic with the type locality sandstones. The Lyons and Permo-Triassic Lykins are exposed at the east entrance to White Ranch Open Space Park and along the west flank of Ralston Creek to Ralston Reservoir, our route in to the Schwartzwalder Mine property.

Permo-Triassic Lykins Formation – Mainly thinly bedded red, sandy and calcareous mudstones, siltstones and shales. The Glennon Limestone member near the top of the formation is mainly pinkish to white stromatolitic limestone. The Glennon forms a relatively prominent but low ridge along the west side of the Schwartzwalder Mine road just south of Ralston Reservoir.

Jurassic Morrison Formation – Usually gray, green, to red claystones, thin lacustrine limestones and tan to reddish alluvial channel sandstones, this unit is not well exposed along the route of our field trip and is generally covered by younger alluvial sediments. The type locality of the Morrison is near the town of Morrison, immediately south of Golden on the extreme southern edge of the field trip area. The town of Morrison is also the site of several of Arthur Lakes' (c.f. Cope and Marsh) famous saurian quarries. The first Apatosaur (a.k.a., Brontosaur) was found at this locality ca. 1877.

Lower Cretaceous Dakota Sandstone – In the locality of the field trip, the Dakota is a prominent former of "hogback" ridges and is well exposed at the I-70 road cut just south of Golden and along Hwy 93 along our route to Coal Creek Canyon. The Dakota Sandstone is the main producer of oil and gas in the Denver Basin immediately east of the field trip area. It is comprised of three main units, in ascending order, the Lytle Sandstone, a mainly light colored, cross-bedded, braided to meandering channel system, the Plainview Sandstone, primarily an estuarine to marine deposit with a few coal zones at its base, and the Skull Creek Shale which overlies the Plainview and represents a period of moderate to deeper water open marine deposition along the Cretaceous Seaway. Overlying the Skull Creek in generally unconformable contact is the "J" or Muddy Sandstone, a sequence of valley-fill deposits near the base, which fine upward and transition to shallow marine, estuarine, and beach deposits. Bones, tracks, mangrove, and abundant trace fossils accompany a transgressive cycle at the top of the sequence.

Upper Cretaceous Benton Group – Generally a valley former in the field trip area and rarely exposed here with exception of outcrops in rail line cuts and quarries near the entrance to Coal Creek Canyon. At the base of the Benton is the silver-gray, siliceous, ammonite-bearing Mowry Shale, followed by the Granerous, a hard, dark gray shale, the Greenhorn Limestone, and the Carlile Shale. The Carlile is made up of the Juana Lopez calcarenite member and the Codell Sandstone (a hydrocarbon producer in some locales of the Denver Basin).

Upper Cretaceous Niobrara Formation – Composed of the Smoky Hill Shale Member and the Fort Hays Limestone at its base. The Niobrara is a gas producer on the eastern flanks of the Denver Basin. The Fort Hays was locally quarried for cement.

Upper Cretaceous Pierre Shale – A thick (>7000 feet) valley-forming highly bentonitic shale unit underlying much of our route along highway 93. Alternating, nearly vertical beds of bentonite pose major geotechnical problems for construction and engineered structures along the Front Range. Three coarsening upward sandy mudstones cycles (the Hygiene Sandstone, the Terry, and the Rocky Ridge Sandstone) occur near the middle of the Pierre. These "tight sand" units produce gas and some oil in parts of the Denver Basin. Several delta front fine-grained sandstone and turbidite deposits occur at the top of the Pierre in outcrops near the southern edge of the field trip area near along Rooney Road immediate south of I-70 and the I-70 hogback road cut.

Upper Cretaceous Fox Hills Sandstone – A white to tan, very fine to fine-grained beach to upper shoreface sandstone, it is the youngest and uppermost marine unit present in the sequence deposited in the Upper Cretaceous Seaway. In conjunction with the overlying Laramie Formation, it forms a major aquifer of the Denver Basin.

Upper Cretaceous Laramie Formation – Mainly delta plain deposits with commercially mineable coals and siliceous clays mined for ceramics. This formation is the main source of coal in the Leyden Gulch coal mine (formerly a Public Service/Xcel Energy gas storage reservoir in process of conversion to water storage for the City of Arvada). Prominent, nearly vertical to overturned hogbacks of the Laramie, bearing the scars of clay mining from the Coors Ceramics operations, are visible at Leyden Gulch on the east side of Highway 93 at the intersection with 82nd Avenue.

Upper Cretaceous Arapahoe Formation – Overlies the Laramie in unconformable, and sharply soured contact. While not exposed in the immediate vicinity of the field trip, outcrops of the Arapahoe do occur on the Colorado School of Mines campus and bear mentioning here. This unit is one of the most distinctive units in the area and is composed dominantly of conglomerates, arkosic sandstone, and minor layers of claystone and siltstone deposited in a braided channel complex. It is important from the standpoint of tectonics in that the composition of the pebbles contained in the conglomerates and arkoses show an inverted sequence of younger to older lithologies (including Precambrian metamorphics and igneous rocks) which tell the story of the "unroofing" of the Rockies during the Laramide Orogeny. (Weimer, 1996)

Upper Cretaceous to Paleocene Denver Formation – Well exposed in the flanks of North and South Table Mountains, the Denver Fm is capped by 64-66 Ma columnar basalt (shoshonite) flows which issued from the Ralston Dikes (visible to west of Highway 93 from intersection of 56th Street to approximately the Ralston Reservoir Dam). The Denver Formation is composed of sandstones, siltstones, and shales, with local conglomeratic channels. Andesitic material, petrified wood, and some dinosaur bones occur near the base. The K-T boundary is mapped near the center of the Denver Formation at the last occurrence of Triceratops.

Paleocene Green Mountain Conglomerate – Dominates the crest of Green Mountain, immediately south of Golden and U.S. Highway 6. It is comprised dominantly of conglomerates, sandstones and siltstones. Local Precambrian lithologies dominate clasts with andesitic materials at the base of the formation.

Pleistocene Alluvium – Five alluvial terrace sequences occur on the east flank of the Front Range and the Denver Basin. The oldest and highest of these, the Rocky Flats Alluvium, caps the Rocky Flats area along our traverse on Highway 93 to Coal Creek Canyon and northward to El Dorado Canyon. The Rocky Flats is, at this locale, armored with quartzite cobbles and boulders derived from the early Proterozoic Coal Creek Quartzite (discussed elsewhere in this field guide). The Rocky Flats alluvium represents the youngest sedimentary sequence in the field trip area with exception of Holocene and present day alluvial and fluvial deposits in local stream valleys and terraces.

PROTEROZOIC ORE DEPOSITS OF THE CENTRAL FRONT RANGE

Stratabound deposits of Pb, Zn, Cu, and W are found in the metamorphosed volcanic rocks and their interlayered sediments. Ores are synsedimentary and stratabound. Base metal sulfides of Pb and Zn range form disseminated to localized to true massive sulfide (>50% sulfide) in small pods to large bodies which were originally tabular or lenticular. Deposits contain up to 10^6 tons of ore minerals. In places the sulfides occur with silicates. Common minerals include: sphalerite, chalcopyrite, galena, gahnite, pyrite, pyrrhotite, tetrahedrite, molybdenite, and other secondary and retrograde minerals. Average metal contents from 55 localities in this and similar Colorado Proterozoic terranes are: 5% Zn, 2.5% Cu, 0.5% Pb, 1-1.6 ounces Ag/ton, and 0.02-0.1 ounce Au/ton (Raymond et al, 1987). Minor amounts of Mo, W, Ni, Co, Cd, Ti, and Bi occur in some of the deposits (Sheridan and Raymond, 1982) along with occasional graphitic zones (Wallace, pers. comm., 1987). W - Cu deposits tend to be peripheral and spatially related to the Pb-Zn sulfides (Sheridan and Raymond, 1982), with scheelite and malachite the predominant minerals. Average Cu content from nine samples is 1.8% (Sheridan and Raymond, 1984). Deposition of the metals in these sulfide deposits probably resulted from exhalation of hydrothermal fluids from sea-floor vents (Raymond et al, 1987). These deposits are most often hosted by more Mg-rich layers (indicating sea-floor metasomatic alteration) of calc-silicates, marbles, or anthophyllite-garnet-cordierite schists and gneisses that occur interlayered with submarine volcanics in the hornblende gneiss unit or transition zone.

Iron-rich metacherts and schists or small Algoman type iron formations occur scattered through the transition zone and occasionally within the hornblende gneiss near its contact with the transition zone. All of the iron-formation facies types can be found in the area of the Schwartzwalder Uranium Mine: oxide facies, carbonate facies, sulfide facies, and silicate facies. The main iron bearing minerals present are magnetite, ilmenite, and hematite (secondary), which occur with various other phases (garnet, grunerite, biotite, muscovite, quartz). The iron is syngenetic and disseminated to massive (~65% $FeO + Fe_2O_3$) in the metasediments. These are also probable sea-floor exhalites related to backarc submarine volcanism, with differences from the base-metal sulfides due to such factors as fluid temperatures, duration and volume of fluid flow, and/or distance from vents.

Thin continuous stratiform layers rich in rutile ± corundum ± topaz (locally to 80% topaz) ± gahnite occur in the upper portion of the interlayered amphibolitic and felsic gneisses (originally bimodal arc volcanics) of the Interlayered Gneiss Unit. Their origin is problematic, but exhalative, weathering, and placer processes have been suggested. The weathering horizon origin is favored due to suggestions of a related minor unconformity (Sheridan, pers. comm., 1987; Marsh and Sheridan, 1976; and Sheridan and Marsh, 1976).

Laramide age U deposits occur in the transition zone associated with faults that cut the hornblende gneiss. U-Pb isotopic studies indicate that U was remobilized from the metavolcanics of the hornblende gneiss (disseminated in it, not originally U ore deposits) with an original age of 1730 ± 130 Ma. (Ludwig et al, 1985). The Schwartzwalder uranium mine has produced 17 million pounds of U_3O_8, with estimated reserves of at least 16 million pounds (Sheridan et al, 1967).

TRIP LOG

Leave Cold Springs Park and Ride
We will travel west then north to Golden via Hwy 6, proceed north on Hwy 93 to the intersection of Hwy 93 and Golden Gate Canyon Road, where we start our mileage log.

Mileage (cumulative and between points)

0.0 0.0 Start mileage log at intersection of Hwy 93 and Golden Gate Canyon Road

Turn west on Golden Gate Canyon Road (at traffic light). We are crossing over Quaternary alluvium. As we approach the mouth of the canyon, the red arkoses of the Pennsylvanian Fountain Fm. will outcrop on the right. Behind us, you can see North and South Table Mountains east of Golden, with capping lava flows of 64-66 Ma shoshonitic basalt. The K-T boundary lies a little below these flows.

0.5 0.5 The Golden Fault and the unconformity between the Fountain (red) and the Precambrian Hornblende Gneiss (grey and black) can be seen to the right. The

Hornblende Gneiss outcrops around the curve ahead. The Golden Fault is the master fault on which over 14,000 feet of uplift of the Front Range occurred in Laramide time. The Fountain is the oldest Paleozoic unit preserved in this part of the Front Range. It unconformably overlies the Precambrian metamorphics, and represents deposition of alluvial fan sediments shed off the uplift of the Ancestral Rockies in Pennsylvanian time. The Fountain is laterally variable, consisting of conglomerates, arkoses, and siltstones. The unit thickens and thins intermittently north to south, the thicker conglomerates and arkoses representing the alluvial fans and the thinner siltstones and claystones representing the interfluvial areas. The unconformity represents a ~1.4 Ga time gap.

0.1 0.6 The contact between the Hornblende Gneiss (black and grey) and the Interlayered Gneiss (pink) is represented in the outcrop to the right (NW) of road by a layer rich in sillimanite and garnet. This layer most likely represents a weathering horizon between the units. There is a small pullout on the left side of the road. From here to the first stop, the Felsic Gneiss of the Interlayered Gneiss outcrops along the road on the right.

0.9 0.9 Stop 1: Mouth of Golden Gate Canyon

Pull off at wide area of road on right.

Interlayered Gneiss: Felsic Gneiss
Calc-Silicate Layers
Hornblende Gneiss

The Interlayered Gneiss Unit consists of interlayered intermediate felsic (dacite to rhyodacite) and mafic (basalt) metavolcanics, interpreted to represent island arc volcanics of the accretionary assemblage. In this area, the felsic volcanics predominate, suggesting proximity to the volcanic center. The kspar-plagioclase feldspar content of the felsic gneiss varies, giving the layers slightly different composition and coloring, pink to grey. Thin layers of calc-silicate indicate submarine deposition of the volcanic layers (figure 7).

The contact with the Hornblende Gneiss Unit is visible in the inside curve along the old roadbed. The dark mafic units represent metamorphosed backarc basalts, and contain some lighter grey metasedimentary layers.

As we proceed up the canyon (called Tucker Gulch) to the next stop, the road more or less parallels the contact between the Felsic Gneiss and Hornblende Gneiss crossing the contact several times. We see both units alternate along the road ahead.

2.2 3.1 You will see an old log cabin and mine structure on the right side of road. This is an old uranium prospect. The Hornblende Gneiss here has a massive dark layer of metabasalt, and a lighter layer of metasediments (figure 9). We will see examples of these up close at Stop 2.

0.8 3.9 Stop 2: Golden Gate Grange Parking Lot

Turn right into the parking lot. Use 2nd driveway entrance.

Hornblende Gneiss: Metamorphosed Volcanics and Sediments
Silver Plume Pegmatite
Joints (Structural)

The Hornblende Gneiss at this stop shows good examples of the amphibolites (metabasalts) and metasediments of this unit (figure 9). To the north, the metasediments are more commonly calcareous. To the south (here) they are more commonly quartzose. These metamorphosed basalts and sediments represent eruption and sedimentation into a backarc basin formed within the volcanic arc environment. The metabasalts may exhibit relict volcanic textures, such as pillows or fragmental textures (figure 10)

The pegmatite in this outcrop is of Silver Plume age, ~1.4 Ga. While most of the pegmatites have not been radiometrically dated, it is commonly accepted that the Silver Plume pegmatites contain kspar > plagioclase, muscovite, often tourmaline, have sharp contacts, and are not foliated.

Note the jointing pattern here, related to Laramide uplift of the Rockies.

Exit Golden Gate Grange parking lot and proceed NW along Golden Gate Canyon Road.

0.1	4.0	Turn right (north) onto Crawford Gulch Road.
0.5	4.5	Note the outcrops of mica schist along road on the right. We have crossed the contact between the Hornblende Gneiss and the Mica Schist. The schist will appear light grey if the sky is cloudy, but silvery and shiny in bright sunlight.
0.6	5.1	Note outcrops of Silver Plume Pegmatites along road on your right. There are several of varying sizes as we drive north. They are similar to the pegmatite at the Grange, but some contain large tourmalines.
1.0	6.1	Cross Van Bibber Creek, a small canyon cut through the schist and pegmatites.
0.1	6.2	Here are more mica schist and pegmatite outcrops along road on the right.
0.8	7.0	More outcrops of mica schist at road level on the right.
1.1	8.1	Turn east onto Belcher Hill Road (at intersection of Crawford Gulch, Belcher Hill, and Drew Hill Roads)
0.4	8.5	Here is a small but zoned Silver Plume Pegmatite along road on the left.
0.8	9.3	Entrance to White Ranch Park, Jefferson County Open Space
0.4	9.7	**Stop 3: White Ranch Park** Park in parking lot at north side of end of road (road ends at locked gate).

Mica Schist
Andalusite Porphyroblasts

White Ranch Park is a wonderful place to see the Mica Schist. There are hundreds of outcrops of schist across the park, and many hiking, biking, and horse trails. The schist is variable, ranging from quartz-rich to highly aluminous (figure 14). We will take a short walk to an outcrop with spectacular andalusite Porphyroblasts (figure 15). This particular unit can be traced laterally, and remains highly aluminous, with various sizes of andalusites. At Stop 3A, this layer crosses the andalusite-sillimanite isograd, and both are present in the outcrop (figure 16). There are several quartz-rich layers of schist; several exhibit relict sedimentary structures, such as cross-bedding and channels (figure 14). The metasediments of the Mica Schist represent pelitic sediments filling the backarc basin. The highly aluminous andalusite-sillimanite rich layers were sediment layers rich in clay minerals, the more quartz-rich schist layers contained more sand and silt.

Retrace route back to intersection of Crawford Gulch, Belcher Hill, and Drew Hill Roads.

1.9	11.6	Turn north (right) onto Drew Hill Road at intersection of Crawford Gulch, Belcher Hill, and Drew Hill Roads.
0.4	12.0	Pavement ends at Homestead Road, outcrop of interest is between the Y arms of Homestead Road and Drew Hill Road
0.0	**12.0**	**Stop 3A - Extra Stop**

Mica Schist
Andalusite + Sillimanite

This small, scattered outcrop is interesting because of the occurrence of both andalusite and sillimanite in the mica schist. The reaction is apparently prograde, and the grains of andalusite and sillimanite are in contact with each other, rather than having the intermediate muscovite present (figure 16). The andalusite-sillimanite masses are large (1-5 cm), and to the west where only sillimanite is present, the sillimanite masses are often 2-5 cm.

0.3	12.3	Safe turnaround at Schoolhouse Road
1.0	13.0	Back to intersection of Crawford Gulch, Belcher Hill, and Drew Hill Roads
7.8	20.8	Retrace route back to Hwy 93
0	**0**	**Original Mileage 0 point**
		Turn north (left) onto Hwy 93 (at traffic light)
0.4	0.4	Turn west onto Pine Ridge Road (Sleigh Off-Road Co. is on NW Corner), follow curve right and proceed northwards. The mountainside to the west is comprised of the Mica Schist. The prominent ridge to the east is the Dakota Hogback, a Cretaceous sandstone unit known for dinosaur trackways and other interesting fossils.
1.8	2.2	Intersection of Pine Ridge Road and 56th Ave. Turn north into gate at sign "Black Forest Mine". We will punch in code at gate and proceed north into Beartooth Ranch gated community. Private Property & Open Range!
0.2	2.4	Turn left at intersection of the mine service road and Glencoe Valley Road. Proceed north.
0.4	2.8	On the west side of road you will see the restoration & reclamation efforts of the old Coors property.
0.2	3.0	Pass the intersection of Dakota Ridge Road
0.4	3.4	15 MPH! Go left at fork, remain on Glencoe Road
0.1	3.5	Pass the intersection with Bear Point Trail Road
0.05	3.5+	Pavement ends. Yellow iron gate – we will open gate with key. Now on Jefferson County Open Space Protected Area. Please respect the wildlife, etc.

As we drive downhill, we approach Ralston Reservoir. In this area we can observe outcrops of Permian Lyons & Permo-Triassic Lykins on the left. The

Lyons Fm overlies the Fountain with fluvial and interfluvial aeolian deposits. The Lykins contains the Glennon Member, a limestone with prominent algal stromatolites.

0.5	4.0	Curve left through road cut in Lyons/Lykins sequence, and past the arkoses of the Fountain Formation.
0.3	4.3	Cattle Guard. Weir and flow station building to right. Ralston Creek now on left.
0.2	4.5	Outcrops of Fountain arkose on right
0.4	4.9	Faulted contact of Precambrian mica schist and Pennsylvanian Fountain Fm. lies close to creek. The mountainside to our left is mica schist, the prominent cliffs on the hillside to our right result from the thick, resistant conglomerates and arkoses of the alluvial fan and braided stream complex in the Fountain. Similar Fountain outcrops comprise the Boulder Flatirons, Red Rocks between Golden and Morrison, and Garden of the Gods in Colorado Springs, among other places less well known along the Front Range.
0.5	5.4	Same contact crosses road here. The knob on the left is schist. Eagle and other raptor nests above on cliff. Bear and mountain lion are common.
0.1	**5.5**	**Stop 4: Schwartzwalder Uranium Mine Road & Property** Outcrops of the Iron Formation begin on the road into the mine. We are on Jefferson County Open Space Protected Area land here. Please respect wildlife and land.

Iron Formation
Hornblende Gneiss

The Transition Zone between the Mica Schist and the Hornblende Gneiss in most places is represented by a thin quartzite (metachert) (figure 18). In the vicinity of the Schwartzwalder Mine, the Transition Zone widens and becomes a small Algoman Iron Formation (figures 12,13). Further on into the mine property where we will drive up the hill, this unit is thicker and better exposed. The outcrops in this canyon on the way in are not as extensive, but still exhibit many of the features of interest. At the northern end of this set of outcrops in the canyon, the iron formation is represented by a magnetite-rich schist. It may not look very different from the Mica Schist, but a magnet will stick to it! As you walk south, the magnetite and quartz contents increase. Relict sedimentary features, such as cross-bedding and troughs, occur in these metasediments.

1.0	6.5	Walk/drive up canyon to wide spot in road. The Hornblende Gneiss outcrops at the north end of this part of the canyon. The outcrop here is massive, dark metabasalt. Drive from here to Schwartzwalder Property trailer office.

Stop 4 Continued

0.8	7.3	Schwartzwalder Property trailer office

Drive up a rugged 4WD road. Please note that the road is rough, narrow, and steep. There are some areas of road washed out by the recent rainstorms. We have flagged the bad stretch – *please use care when driving up and down this section of road.*

1.1	8.4	Top of the road, there is a wide area to park. We have flagged the 2 monitor well caps in the parking area, ***PLEASE BE CAREFUL NOT DRIVE ONTO THESE WELL HEADS!!!!!***
		We will now walk to the areas of interest, flagged by orange surveyor's tape.
		The first outcrops are of the iron formation, oxide facies. Massive magnetite-chert, and garnet-magnetite schist with some relict sedimentary structures outcrop along our path.
		A hike to the neighboring ridge will take us through the calc-silicate gneiss of the Hornblende Gneiss Unit. Outcrops are poor and weathered in the valley and on slopes. As we reach the higher part of the ridge, we cross into the amphibolite of the unit. Outcrops are variable, with amphibolite (metabasalt) interlayered with some calc-silicate and ultramafic lithologies. Relict volcanic textures can be observed at some spots. Pillows, vesicles, flow structure, etc. will be pointed out.
		Retrace route back to intersection of Pine Ridge Road and 56th Ave
5.2	13.6	Turn east onto 56th Ave and proceed to Hwy 93. View of Ralston dikes to north. These are the feeder dikes of the 64-66 Ma lava flows that cap North and South Table Mountains east of Golden.
0.2	13.8	Turn north onto Hwy 93. From this point to the turnoff to Coal Creek Canyon, we will drive past many outcrops of Cretaceous and Tertiary sedimentary units. Please refer to the descriptive portion of this field guide for more information about these units.
3.0	16.8	View to left of Ralston Reservoir dam. The gravel quarry operation to the south is quarrying rock from the Ralston dikes.
1.4	18.2	On right at Leyden Gulch is a hogback of the Cretaceous Laramie Fm, delta-plain sandstones, siltstones, claystones, and coal derived from the Laramide uplift of the Rockies. The Leyden Coal Mine, active in the early part of the 20th century, lies behind the hogback to the east. The mine was later used by Public Service (now Xcel) Energy for gas storage, and is currently being converted for local municipality water storage.
1.6	19.8	Turn west onto Hwy 72 (at traffic light). We are now on the Rocky Flats Alluvium surface.
1.85	21.6+	*Turn south onto Blue Mountain Drive. We will skip to next* if roads are icy. As we drive south, the ridge to the left is Fountain Fm. The mountainside to the right is Precambrian Interlayered Gneiss.
1.55	23.2	Turn west (right) on Ute Drive
0.2	23.4	Turn uphill (left) onto Westridge Drive, proceed uphill
0.9	24.3	Intersection Westridge Drive and Brumm Trail. Westridge Drive goes to left, Brumm Trail is straight ahead. Turn northwest onto Brumm Trail.
0.6	**24.9**	**Stop 5: Old Booth Ranch Property (Weather/Time Permitting)**
		Interlayered Gneiss: Mafic and Felsic Gneiss
		Boulder Creek Pegmatites
		At this point we are back into the Interlayered Gneiss, at the northern end of the syncline. Here the Mafic Gneiss predominates (figures 4,6), with layers of Felsic

Gneiss also present (figure 7). There are also several small pegmatites, but they are plagioclase-rich, biotite rather than muscovite, no tourmaline, and are generally foliated. These are interpreted as Boulder Creek pegmatites. The Felsic Gneiss here is finer grained than at Stop 1, and in thinner layers. The Mafic Gneiss is salt-and-pepper in appearance, a fine to medium grained amphibolite interpreted as metamorphosed island arc basalts. There are intrusive Hornblendite bodies (metamorphosed ultramafic intrusives) present here (figures 6,8). Relict phenocrysts now form eyes of tremolite apparent on the weathered surface of an outcrop.

3.3 28.2 *Retrace route back to Hwy 72, turn west (left) onto Hwy 72. The steep, rugged mountains here are composed of the Coal Creek Quartzite.

1.6 29.8 On the left we will see a massive outcrop of quartzite. The quartzite at this outcrop is from unit C, and is fairly dark in color (grey to purplish), more massively bedded, and contains more mica and andalusite than units A and B. As we drive up the canyon, we will see more outcrops of the quartzite. Some of these contain stretched pebble conglomerates.

2.1 31.9 Stop 6: Coal Creek Canyon

Coal Creek Quartzite

Boulder Creek Batholith, Quartz Monzonite

We will pull off to the right onto a wide shoulder past the quartzite outcrop and walk back to it. On the short walk, we will first see the quartz monzonite of the Boulder Creek pluton. It is intrusive into the quartzite. The older granodiorites have been dated at 1714 Ma, the quartz monzonites a little younger. These represent syn-tectonic intrusions as the area became part of the magmatic arc.

The quartzite outcrop here is the basal unit A (figure 17). There are several interesting relict sedimentary features in this outcrop, and a sequence of stacked, fining-upward units of a few meters thickness each. Most of the units are marked by a basal conglomeratic unit with usually scoured bases. The conglomeratic units fine- upward to small-scale trough-type cross bedding then to more planar-laminar like structures. Grain-size appears to decrease upward in relation to the change of sedimentary structures. Some indication of imbricate structures is present within the conglomerate beds. More distinct and well-developed channels, up to several 10's of meters across and with deep scouring at their base occur in equivalent units further to the northeast at Eldorado Canyon. Large-scale trough-type cross beds also occur at the Eldorado locale.

0.3 32.2 Chapel of the Hills turnoff. This is a good place to safely turn around and retrace route back to Cold Springs Park & Ride

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***Jefferson County Open Space** for access to environmentally sensitive raptor nesting areas of White Ranch Open Space Park, normally closed to the public.*

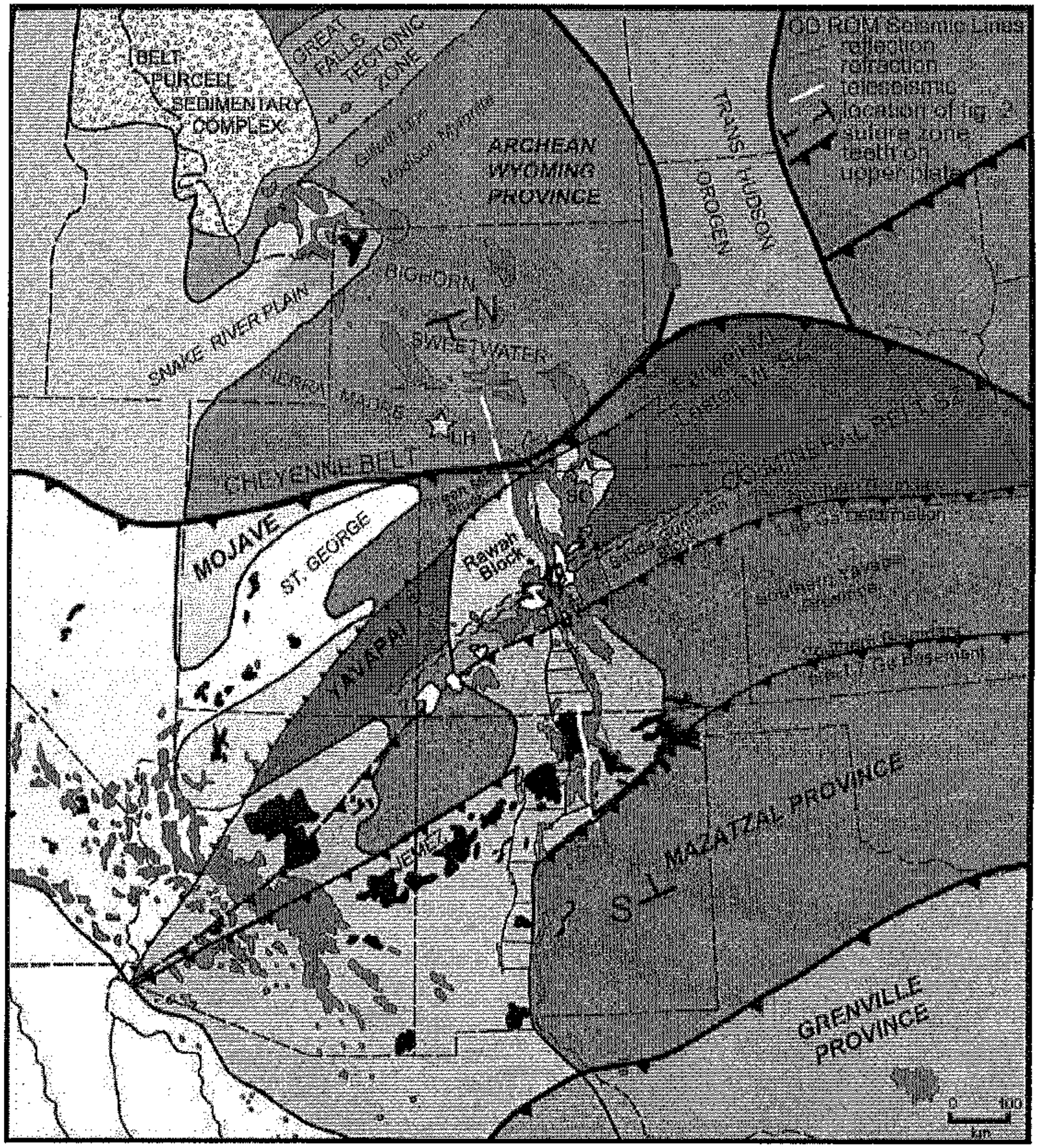
***The Beartooth Ranch Homeowners Association and the Blue Mountain Homeowners Association** for their courtesy and permission to cross their properties.*

***Colorado Scientific Society** for their support and trial runs of this field trip and helpful comments from participants.*

"Take Only Photos, Leave Only Footprints!"

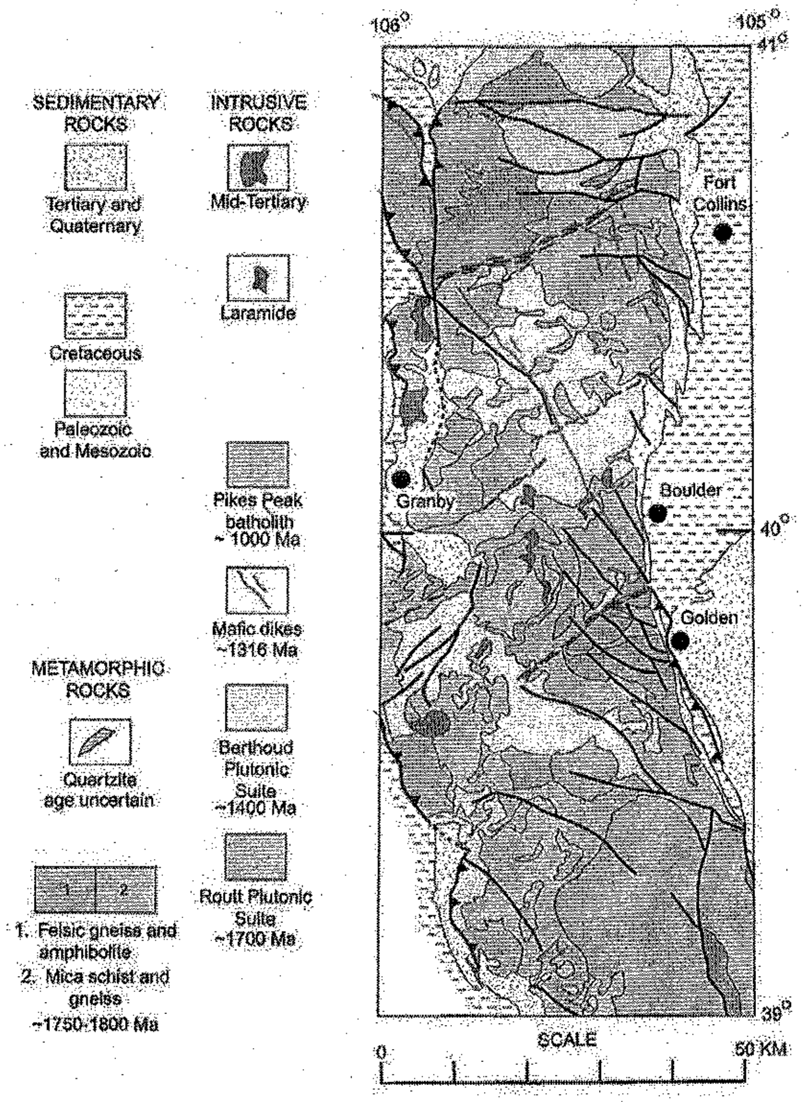
Geologic elements of southwestern North America

Figure 3. Geologic elements of southwestern North America. The CD-ROM Working Group has suggested several provinces in the accretion of North America. (map from CD-ROM Working Group, 2002)



From CD-ROM Working Group, 2002

Colorado Front Range Geology



From J.Reed, 2004

Figure 4. Precambrian units of the Colorado Front Range.(with permission from J.C.Reed, 2004)

Central Front Range Geology

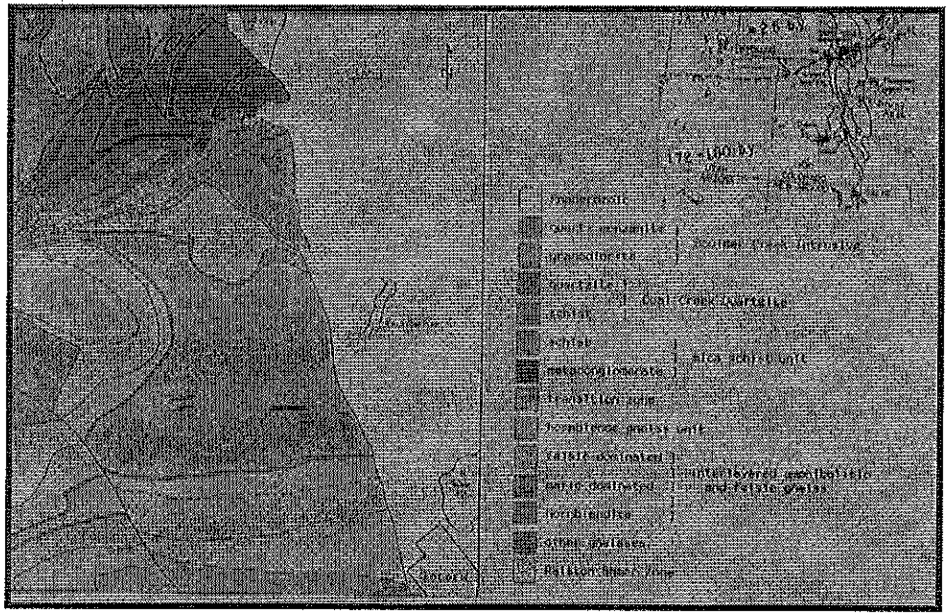


Figure 5. Geologic map of the field trip area. (after Finiol, 1992)

Mafic Gneiss & Hornblendite

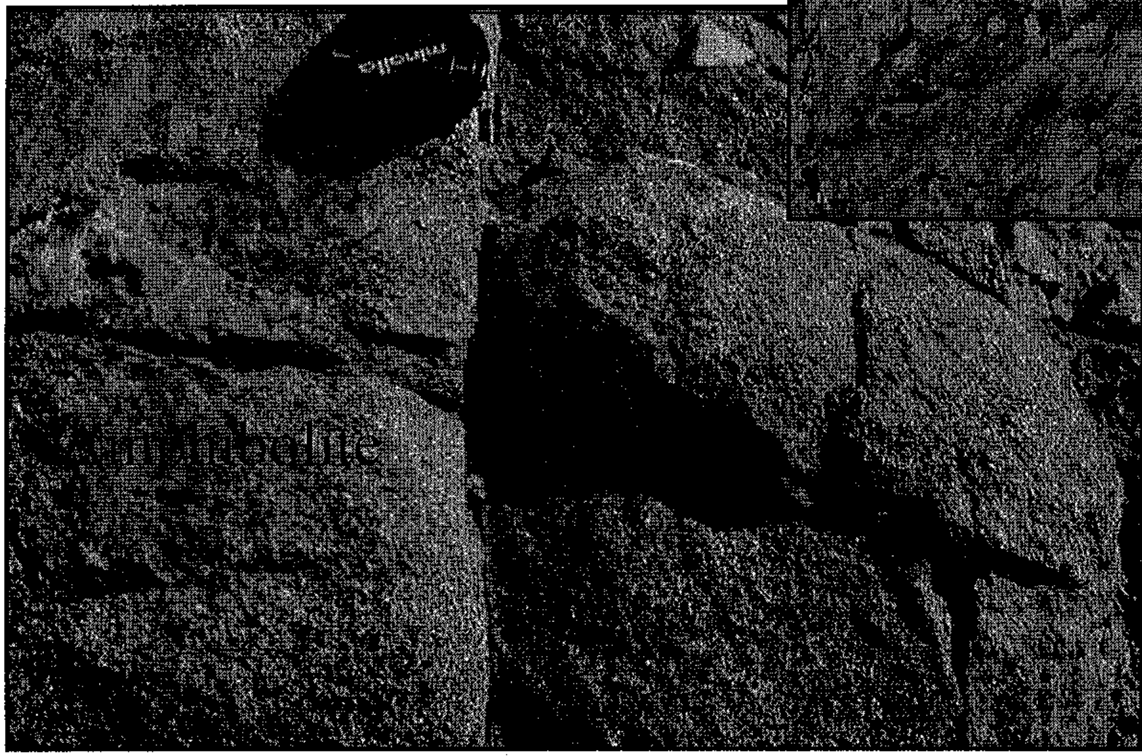


Figure 6. Amphibolite and hornblendite of the mafic gneiss, Interlayered Gneiss Unit north end of the area, on former Booth Ranch property (now Blue Mountain Subdivision) at Stop 5. Hornblendite – Note the relict phenocrysts as "eyes" on the weathered outcrop surface, now tremolite

Felsic Gneiss

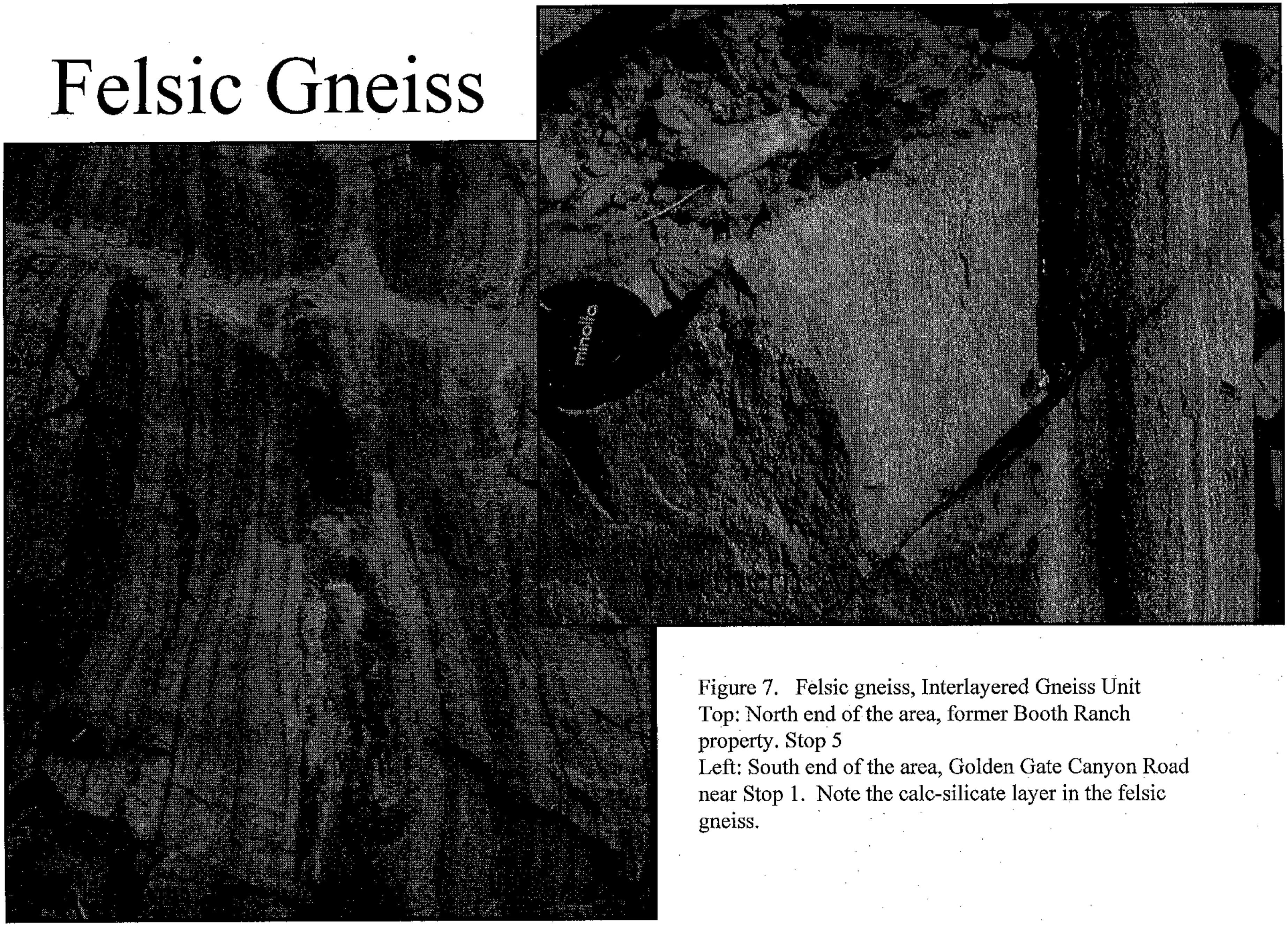
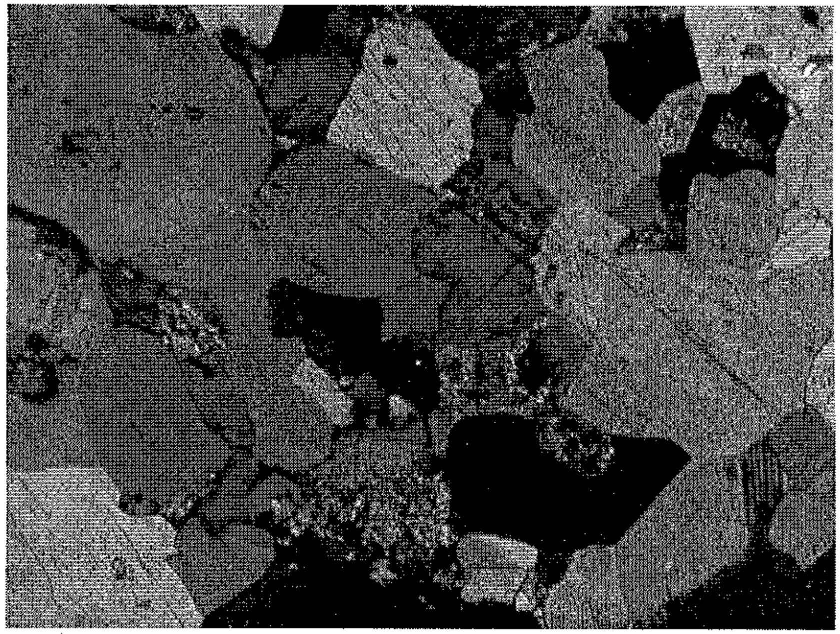


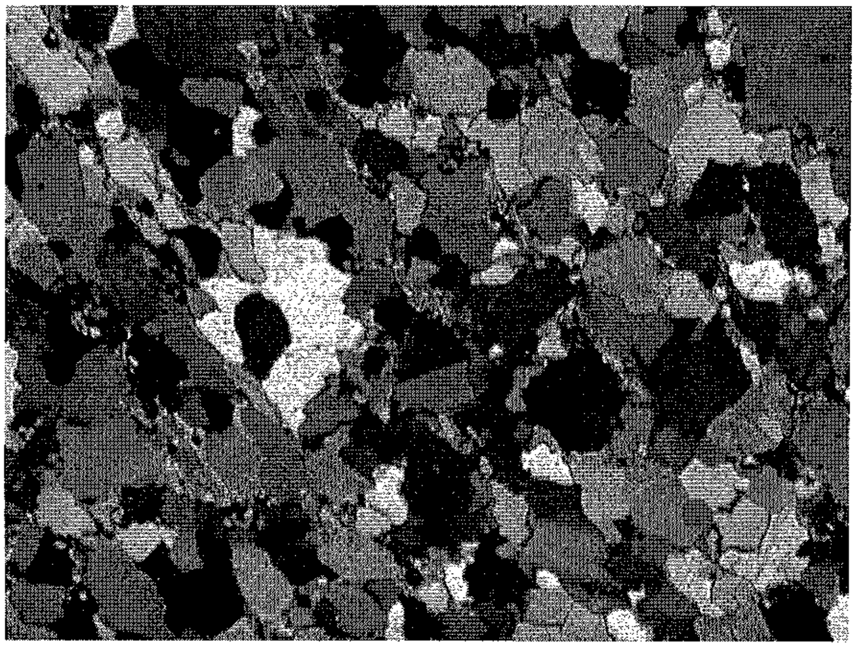
Figure 7. Felsic gneiss, Interlayered Gneiss Unit
Top: North end of the area, former Booth Ranch property. Stop 5
Left: South end of the area, Golden Gate Canyon Road near Stop 1. Note the calc-silicate layer in the felsic gneiss.

Photomicrographs of the Interlayered Gneiss

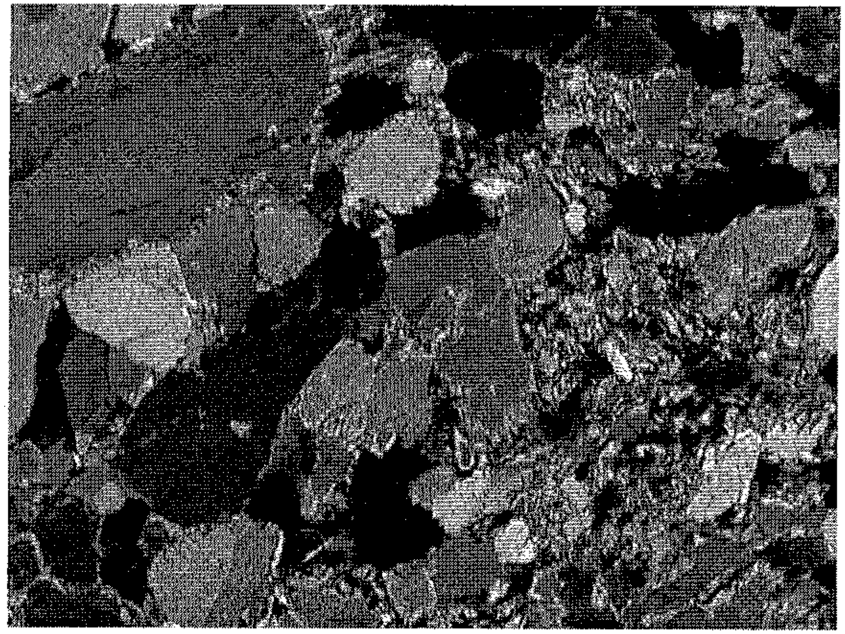
Figure 8. Photomicrographs of the Interlayered Gneiss Unit



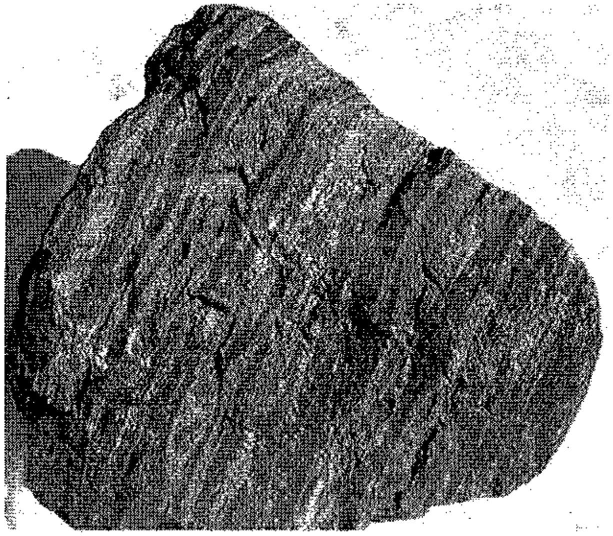
Amphibolite



Felsic Gneiss



Hornblendite



Amphibolite with Calc-Silicate

Hornblende Gneiss

Figure 9. Amphibolites and metasediments of the Hornblende Gneiss Unit.
Top: Amphibolite from south end of area.
Left: Outcrop of the interlayered amphibolite and metasediments from south end of area.
Top left: Interlayered amphibolite and calc-silicate from north end of area, Schwartzwalder Mine property.

Relict Volcanic Textures

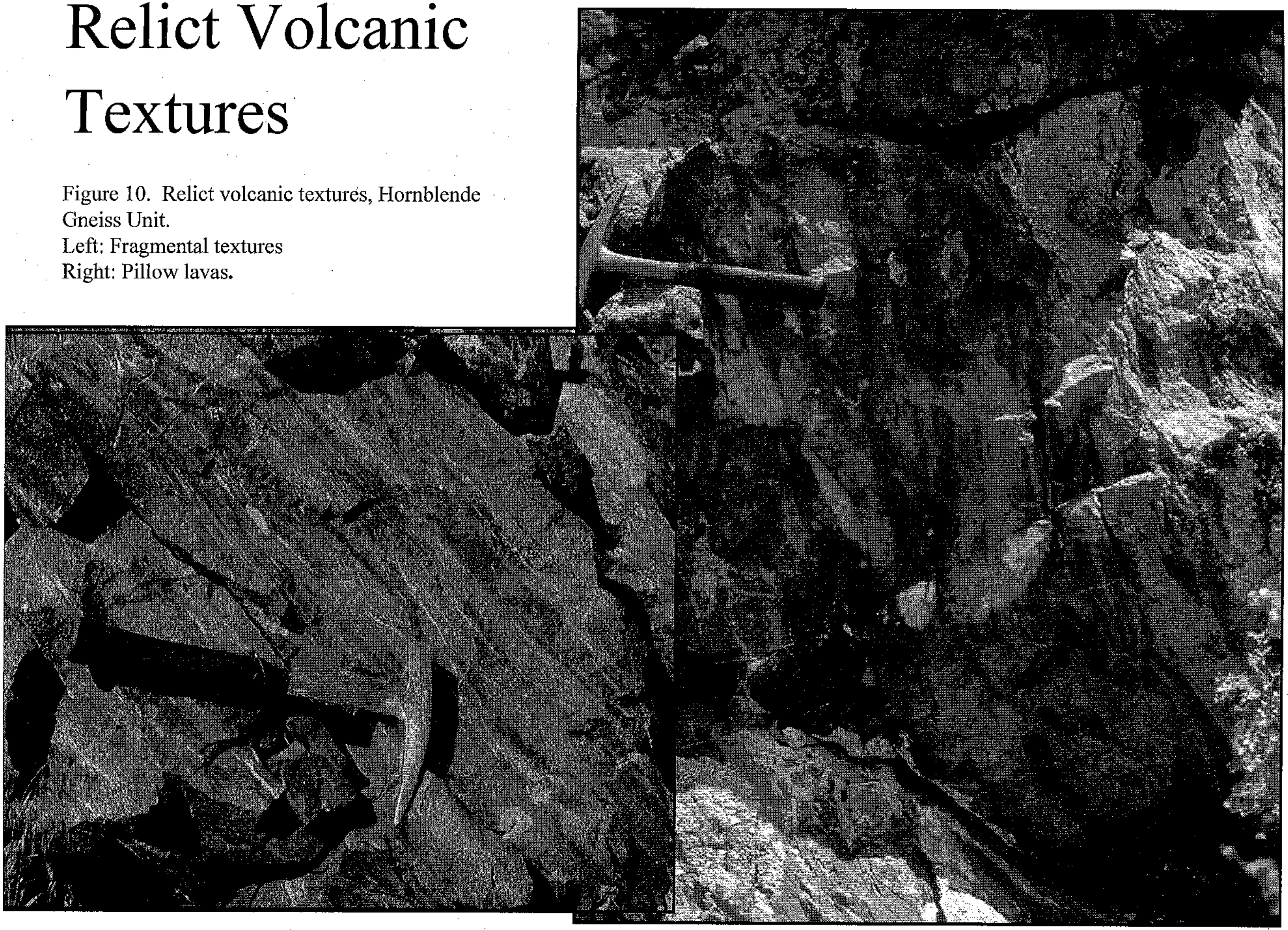
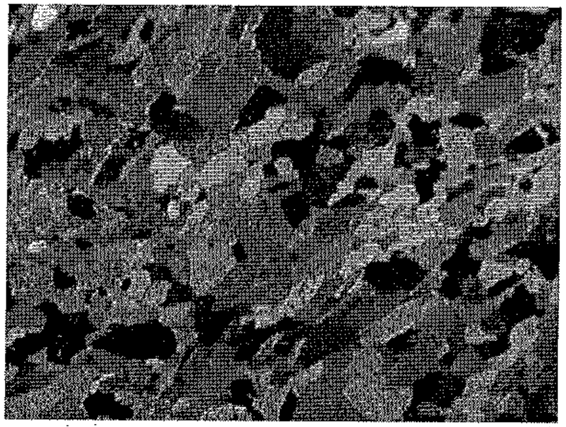


Figure 10. Relict volcanic textures, Hornblende Gneiss Unit.
Left: Fragmental textures
Right: Pillow lavas.

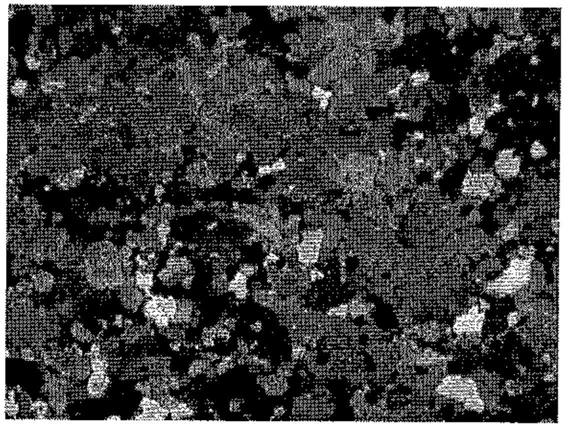
Photomicrographs of the Hornblende Gneiss

Figure 11. Photomicrographs of various phases of the Hornblende Gneiss Unit.

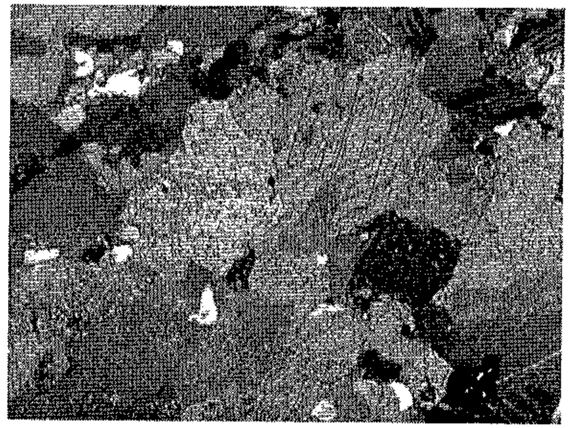


Amphibolite

Metagreywacke



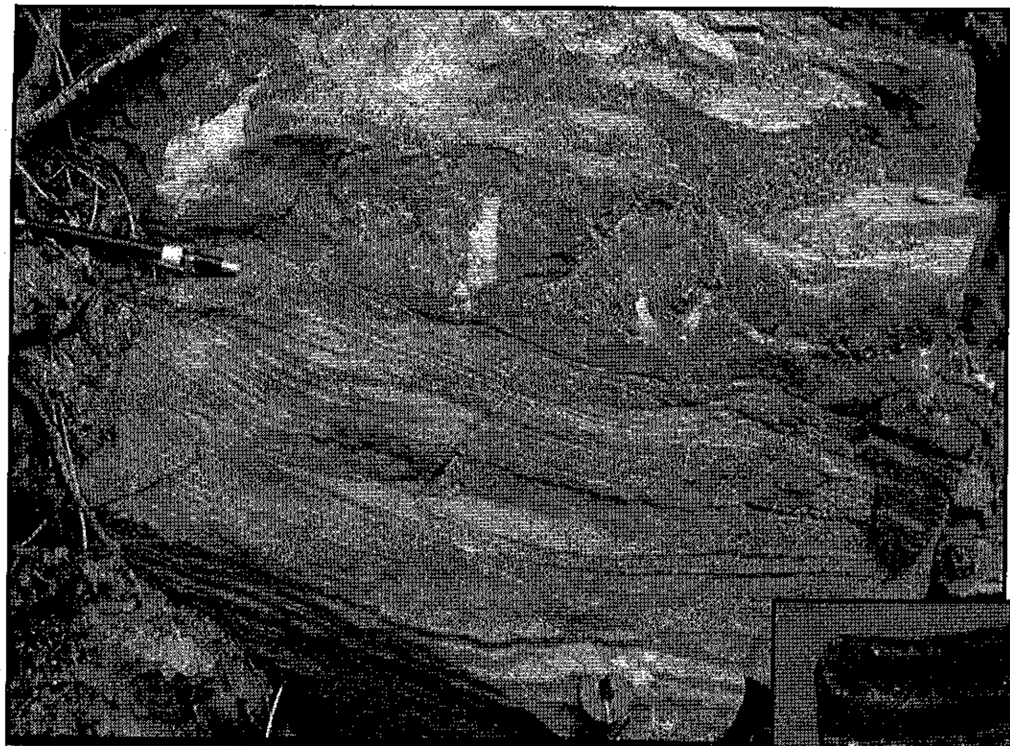
Calc-Silicate



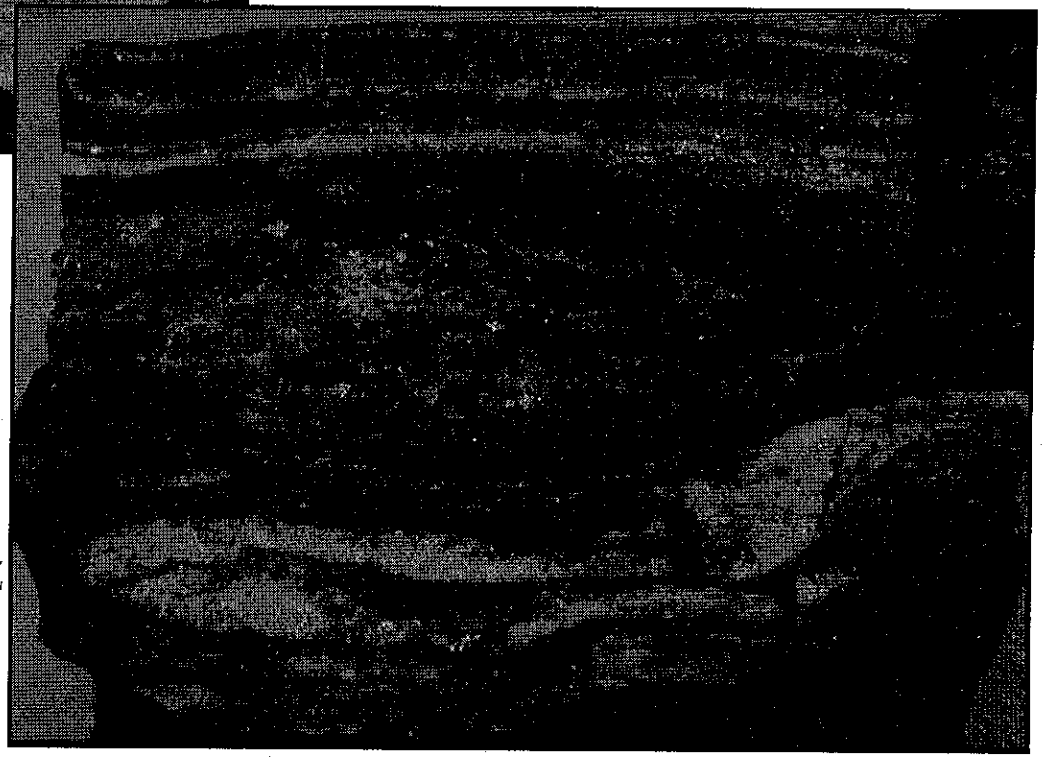
Marble

Iron Formations

Figure 12. Iron Formation of the Transition Zone.



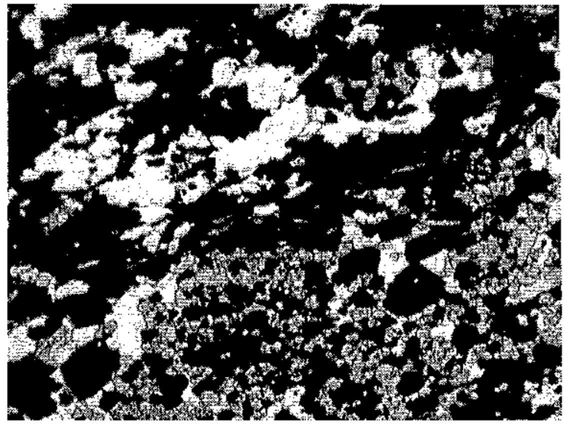
Garnet-Magnetite Schist



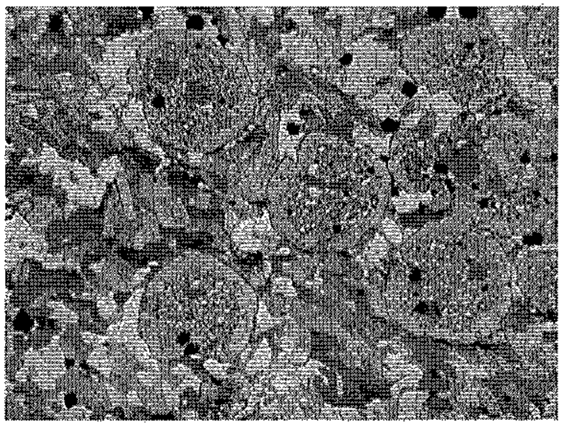
Magnetite & Quartz

Photomicrographs of the Iron Formations

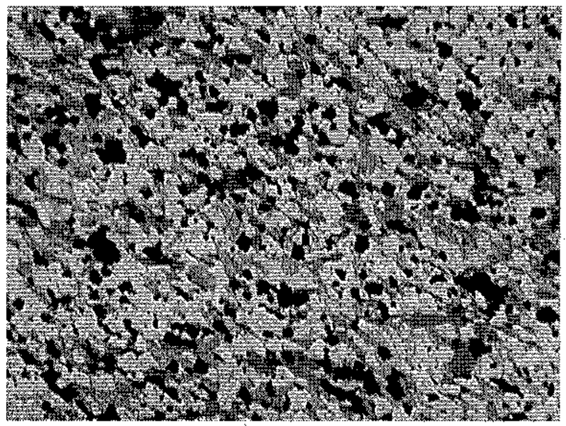
Figure 13. Photomicrographs of various phases of the Iron Formation.



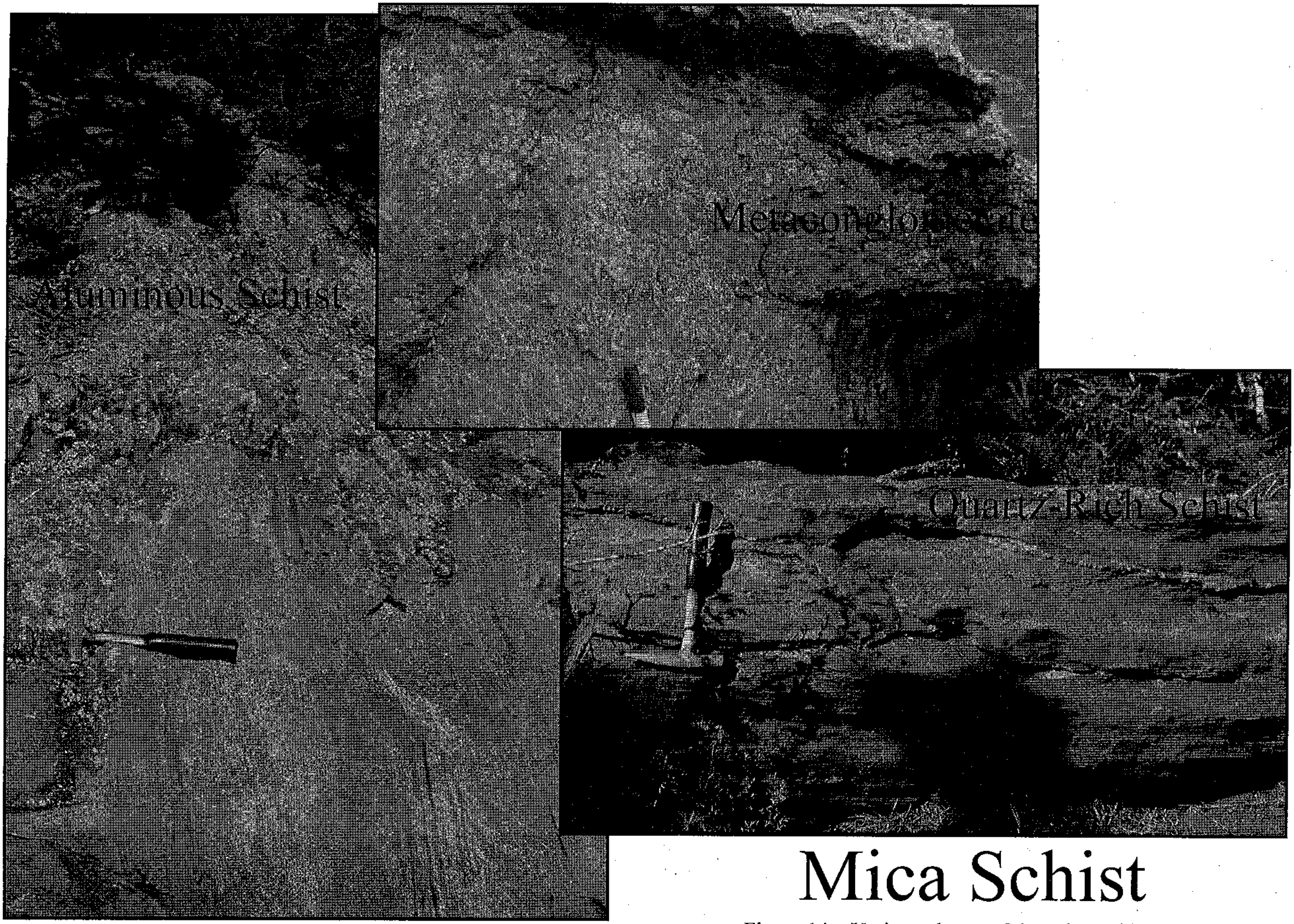
Magnetite & Quartz



Garnet-Magnetite Schist



Magnetite Schist

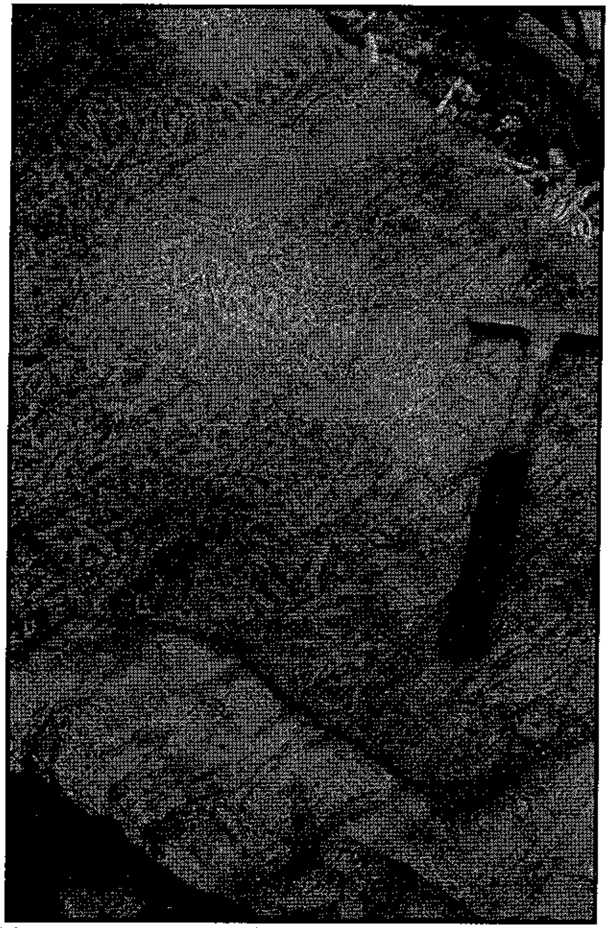


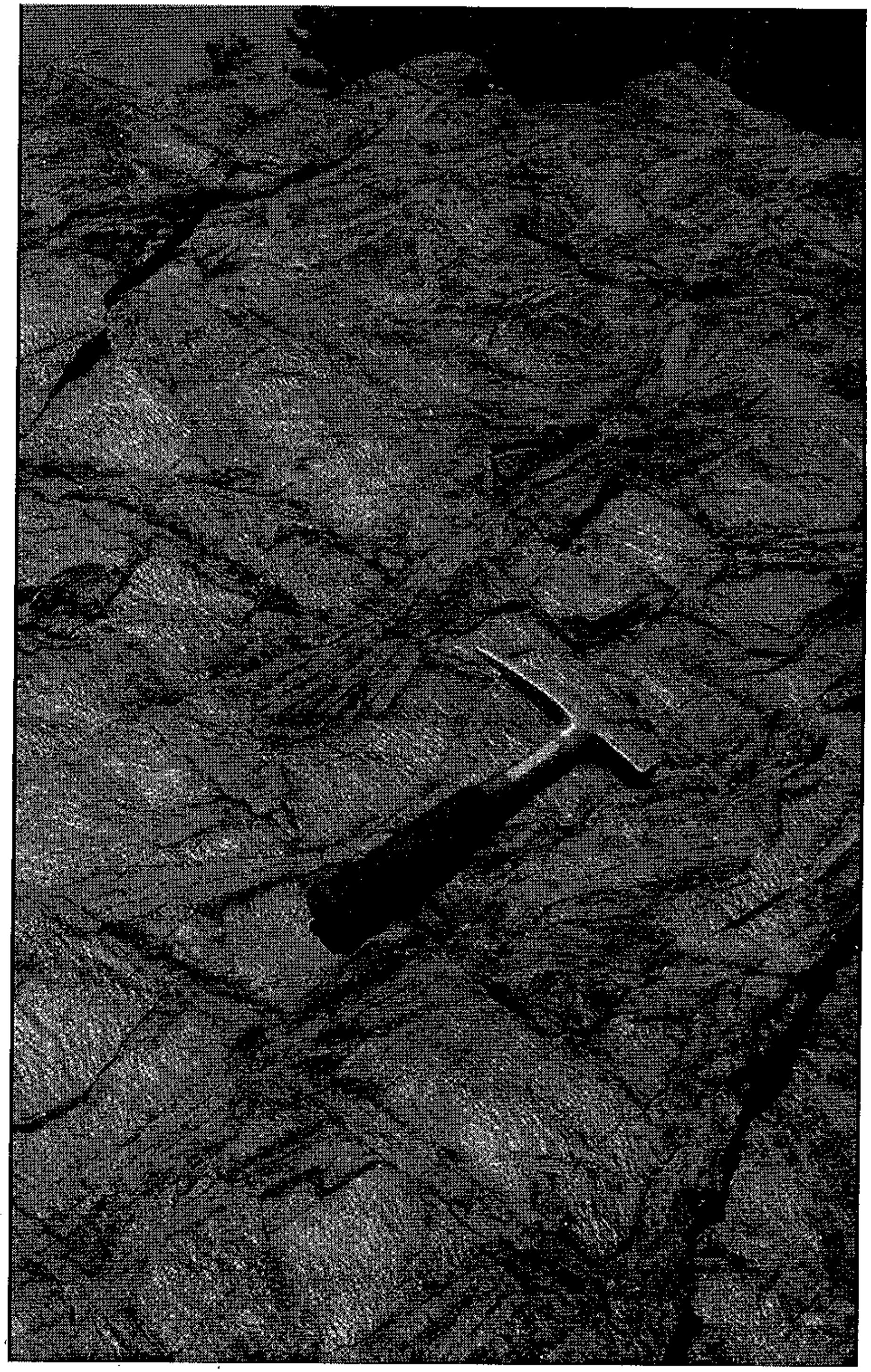
Mica Schist

Figure 14. Various phases of the Mica Schist Unit.

Andalusite Porphyroblasts

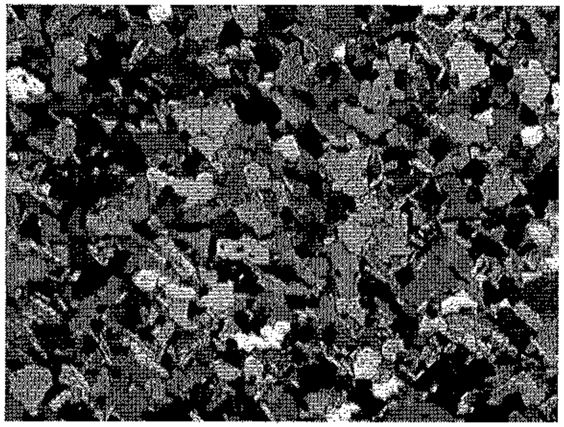
Figure 15. Large andalusite porphyroblasts in Mica Schist



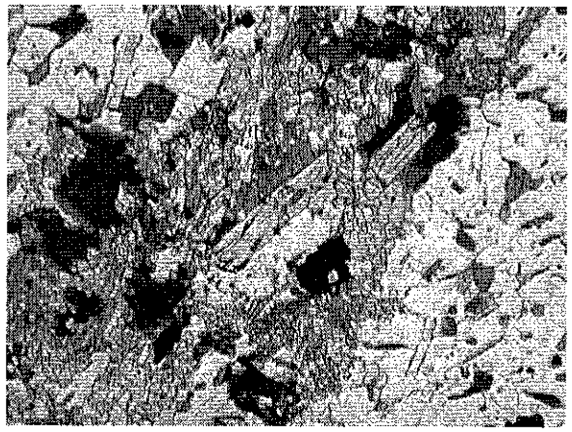


Photomicrographs of the Mica Schist

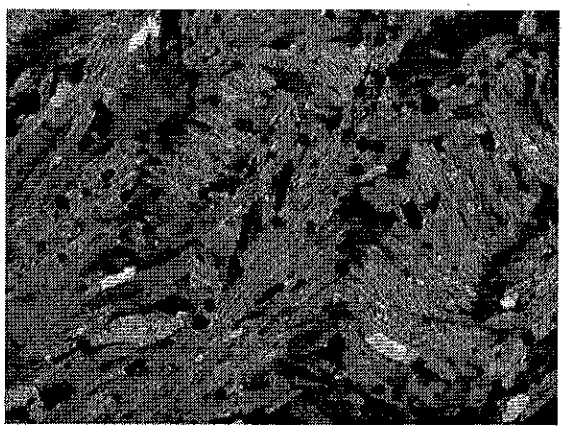
Figure 16. Photomicrographs of various phases of the Mica Schist Unit.



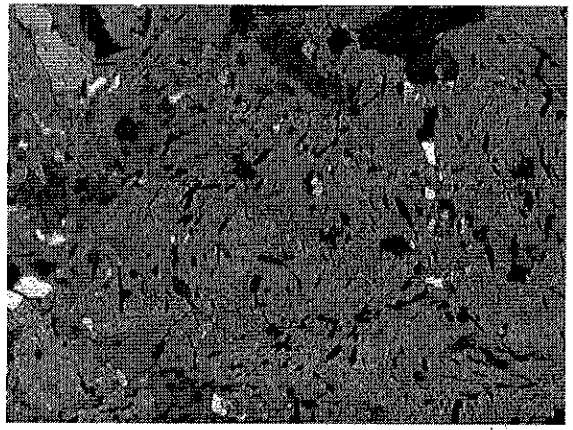
Quartz-Rich Schist



Andalusite-Sillimanite Schist



Crenulated Muscovite Schist



Andalusite Porphyroblast

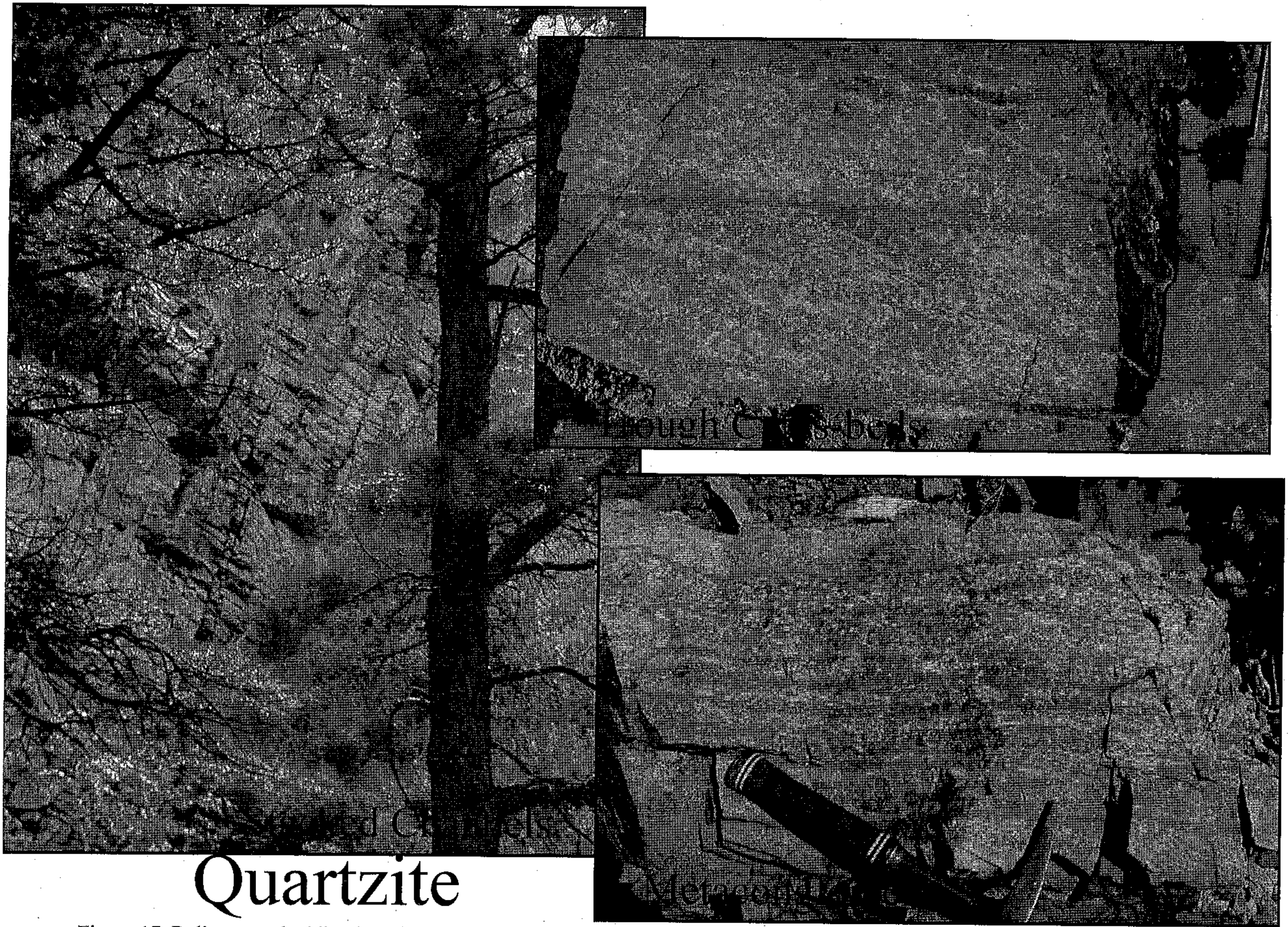
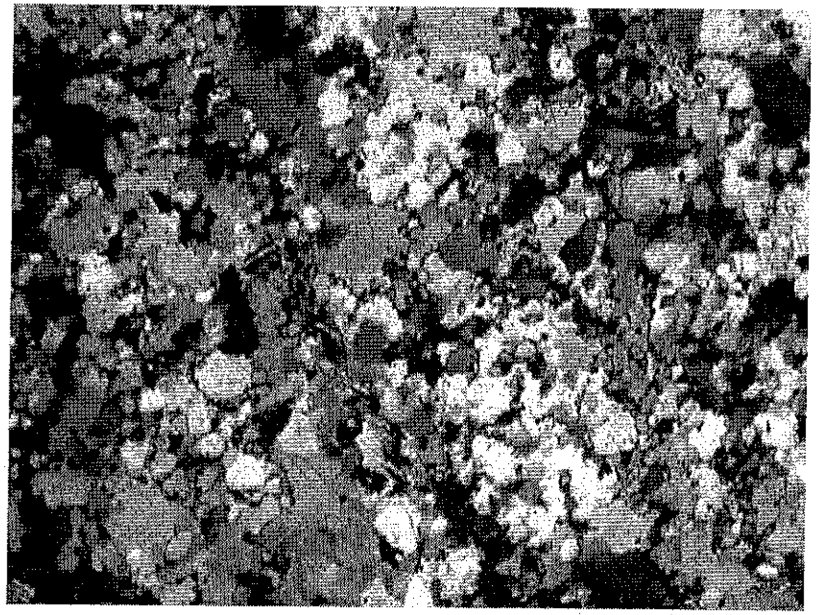


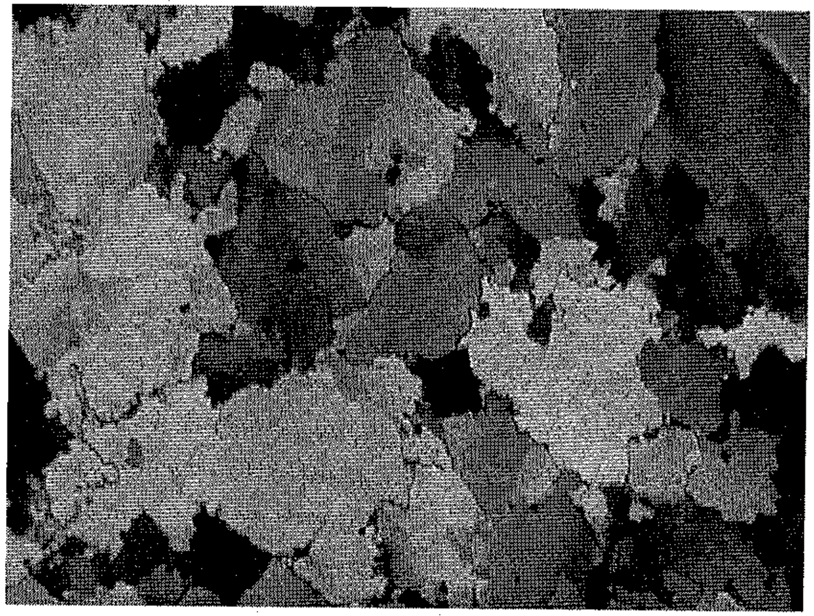
Figure 17. Relict cross-bedding in unit A of the quartzite.

Photomicrographs of Quartzite

Figure 18. Photomicrographs of quartzite from the Transition Zone and Coal Creek Quartzites.



Coal Creek Quartzite
(Clastic)



Transition Zone Quartzite
(Chert)

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