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Reactivation (long-term evolution) of Silvia-Pijao Fault along the "Quebrada La Maizena "western flank of Central Cordillera, Quindio-Colombia.

GUILLERMO CAMARGO [1]
JAIRO MOJICA[2]
[1] Departamento de Geociencias, Universidad Nacional de Colombia, Apartado 14490, Bogotá.
E-mail: gacamargoc@unal.edu.co
[2] E-mail: jairomojica@hotmail.com

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ABSTRACT

The macro and microstructural characteristics of rocks along the lower portion of the "Quebrada la Maizena", in the influence zone of the Silvia- Pijao Fault, one of the major faults related to the Romeral Fault Zone (RFZ), allow to interpet a long history of deformation. These rocks belong to the Quebradagrande and Arquía Complexes. Along the section, structural data and samples for thin sections analysis were obtained mostly in the western block adjacent to the main fault trace. Metamorphic rocks include amphibolites and hornblende - garnet - zoisite ± chlorite ± muscovite ± graphite schists. Igneous bodies are granodiorite and highly serpentinized dunite. Sedimentary rocks are mostly sandstones and calcareous mudstones. These sedimentary rocks exhibit faulted contacts and lenticular geometry. Most fault rocks are brittle cataclastic rocks. They include breccias, microbreccias, gouge and foliated gouge. In some samples, plastic deformation is inferred from microscopic bands of reduced grain size (mostly in quartz), deformation bands and undulose patchy and sweeping extinction in quartz, and to a lesser extent in plagioclase, indicating an incipient development of mylonitic textures formed at low-grade metamorphic conditions. This suggests an older record of localized deformation. These microstructures and other outcrop scale structures such as thrust systems (duplexes and imbricates), strike-slip and normal faults with dip and oblique components of movement, tectonic foliation, varying fault cross-cutting relationships and presence of sedimentary slices and ultrabasic serpentinized bodies along the fault zone suggest a multi-state brittle deformation and multiple reactivation of some of the fault zones.

Key words: Structural evolution, Romeral Fault Zone, Silvia-Pijao Fault, Microtectonics, Faulting, Fault rocks, Quindío- Colombia, West flank of Central Cordillera.

RESUMEN

Las características macro y microestructurales de las rocas aflorantes en la parte baja de la ¨Quebrada La Maizena¨, en la zona de influencia de La Falla Silvia-Pijao, una de las fallas principales asociadas al Sistema de Fallas de Romeral (SFR), permiten interpretar una larga historia deformativa. Estas rocas pertenecen a los Complejos Quebradagrande y Arquía. A lo largo de la sección, datos estructurales y muestras para secciones delgadas fueron obtenidas principalmente en el bloque occidental adyacente al principal trazo de la falla. Rocas metamórficas incluyen anfibolitas, y esquistos de hornblenda, granate, zoicita, clorita, muscovita y grafito. Rocas ígneas son granodioritas y dunitas altamente serpentinizadas. Las rocas sedimentarias son principalmente areniscas y lodolitas calcáreas. Estas rocas sedimentarias muestran contactos fallados y geometría lenticular. La mayoría de las rocas de falla son de origen cataclástico e incluye brechas, microbrechas, harina de falla (gouge) y gouge foliado. En algunas muestras se presenta deformación plástica no bien desarrollada, inferida a partir de bandas microscópicas de granos de cuarzo (reducción de tamaño de grano), bandas de deformación, extinción undulosa y en parches, y en menor proporción en plagioclasas indicando un incipiente desarrollo de texturas miloníticas formadas en ambientes metamórficos de baja temperatura sugiriendo un registro mas antiguo de deformación localizada. Estas microestructuras sumadas a otras a escala de afloramiento tal como sistemas de cabalgamientos (duplexes y abanicosimbricados), fallas de rumbo y normales con componentes de movimiento oblicuos, foliación tectónica, fallas con variables relaciones de corte, presencia de escamas sedimentarias y cuerpos ultrabasicos serpentinizados a lo largo de la falla sugieren numerosos eventos de deformación frágil y reactivación múltiple de algunas de las zonas de falla.

Palabras claves: Evolución Estructural, Fallamiento, Falla de Silvia-Pijao, Flanco occidental de la Cordillera Central, Microtectónica, Quindío-Colombia, Rocas de falla, Zona de Falla de Romeral.

INTRODUCTION

Colombia is located in the northwestern part of South America in the area of interaction of four different tectonic plates: The South American to the east, Caribbean to the north, and Cocos and Nazca to the west (Pennington 1981, Kellogg & Bonini 1982). In this tectonic context, there is a first order feature of prime importance in the Colombian geological configuration. It is the Romeral Fault Zone (RFZ), located in the western flank of the Central Cordillera of Colombia, extending for more than 900 kilometers through Colombia and Ecuador. Most of the interpretations about Colombian Andes agree that the RFZ represents a "paleosuture" or a paleosubduction zone (Restrepo & Toussaint 1973, Aspden & McCourt 1986, Feininger 1982, MacDonald et al. 1996). This fault zone separates two distinct types of rocks: continental and oceanic affinity rocks to the east and west respectively (Case et al. 1971). Several different types of studies have been conducted on this important tectonic feature; however, very little has been done in order to understand the structural evolution of the rocks involved. The purpose of this work is to evaluate the deformation (macro and micro structures) in the western block of the Silvia-Pijao Fault (one of the faults of the RFZ), just adjacent to the main fault trace, in order to establish if this fault zone has been subjected to one or more periods of deformation through time. This work reports and describes the different types of rocks involved in the section studied, as well as the main geometrical and textural features at outcrop and microscopic scales. Classification of fault rocks partially follows that of Sibson (1977). Kinematic indicators are based on Petit (1987). Thin sections were prepared perpendicular to foliation and parallel to lineations.

Location

Regional geologic fieldwork was initially carried out in an area of approximately 400 km² from the towns of Génova (to the south) to Salento (to the north), and encompasses small towns such as Pijao, Barragán, Buenavista and Córdoba (Fig. 1). The area is highly forested and humid, road outcrops are usually not good and lack continuity; therefore, river and creek cuts are the most valuable places to look for geologic information. The regional geological survey allowed us to choose the "Quebrada La Maizena" because it provides very interesting petrological and structural features. Igneous, metamorphic and sedimentary rocks crop out providing the opportunity to study their relationships. In addition, previous maps show that the section is affected by the Silvia-Pijao Fault. This fault has been previously mapped for dozens of kilometers from the southern part of the Central Cordillera to the north of the study area. In the geologic map of Quindío (González & Núñez 1991) the fault separates two different lithological units, the Arquía Complex and the Quebradagrande Complex (sensu Maya & González 1995).

Geologic and Tectonic settings

Five different units have been proposed and mapped in previous works (González & Núñez 1991) to describe the lithological configuration of the area, from west to east: 1. The Amaime Group, characterized by basalts of oceanic plateau of Cretaceous age (Nivia 1987), 2. The Arquía Complex, composed of middle-high grade metamorphic facies rocks such as amphibolites and schists of Cretaceous age (Maya & González 1995) and Paleozoic age (McCourt & Feininger 1984), 3. The Quebradagrande Complex is composed of sedimentary and volcanic members (Cretaceous age), 4. The Córdoba Igneous Complex, characterized mainly by granodiorite and diorite, dated 72-79 Ma by K/Ar (McCourt et al. 1984), and 5. The Cajamarca Complex, composed of sericite- quartz-sericite, actinolite-chlorite and graphite schists, and phillites and slates of probable Paleozoic age (Nelson 1962). Regional faults separate these units. The westernmost fault is the Cauca-Almaguer Fault (main Romeral Fault) which separates oceanic basalts to the west from amphibolites of the Arquía Complex to the east. This fault is described as the westernmost fault of the RFZ (Gonzáles & Núñez 1991). To the east of the previous fault, the Silvia-Pijao Fault takes place. Along this fault, serpentinized ultramafic bodies are present. This fault separates the Arquía and Quebradagrande Complexes. Next to the east, there are some regional faults including the San Jerónimo Fault that separates the Quebradabrande and Cajamarca

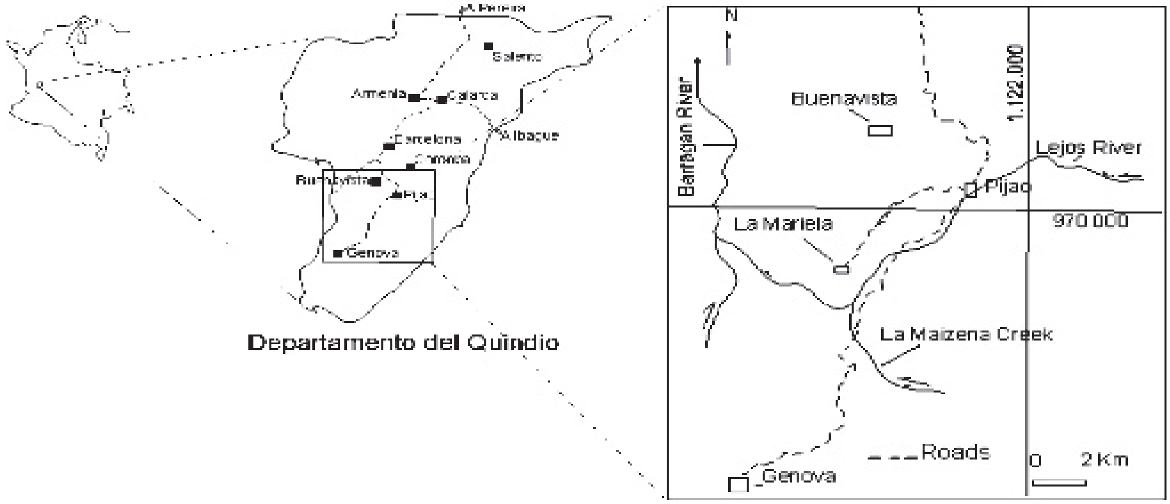


FIG. 1. Location of the section of "Quebrada la Maizena" and surrounding areas.

Complexes. This last unit constitutes the core of the Central Cordillera of Colombia.

Tectonic interpretations of the Colombian Andes involving the RFZ have been proposed by Restrepo & Toussaint (1973), McCourt et al. (1984), Aspden & McCourt (1986), Etayo et al. (1983). The RFZ has been interpreted as the paleosuture of an accreted Terrane (Restrepo & Toussaint 1973, MacDonald et al. 1996, McCourt et al. 1984) equivalent to a paleoplate margin. McCourt et al. (1984) interpret the western part of the Colombian Andes as a composite margin made up of successively-accreted oceanic island arc related sequences. The age of the RFZ has been estimated to be as old as 125 Ma (McCourt et al. 1984). The width of the zone of deformation has been proposed to be from a few meters to several kilometers (González 1977, Toussaint & Restrepo 1976). McCourt & Feininger (1984) report a wide band of 1.2 to 2 km of high pressure rocks (blueschists) some 15 or 20 km east of the main Romeral Fault near the town of Barragán (Valle). Some general observations about the nature of the fault-rocks involved have been shown by González (1977) who pointed out the great variety of fault rocks related to this fault zone (in a regionally different locality) such as mylonites, protomylonites, ultramylonites, mylonitic-blastomylonitic gneisses, cataclasites and associated processes of brecciation and recrystallization.

METHODS

The geologic section was measured by tape and compass in order to have an accurate location of observations and samples. The section was studied from the convergence of the "Quebrada la Maizena" with the Lejos River in an upstream direction (Fig. 2).

Petrographical and structural observations (structural geometry, fracture orientation and shear-sense indicators) were recorded in the field. Particular attention was paid to fault zones and other deformational features. Forty-four samples were obtained to make thin sections (FIG. 3). The classification with the basic mineralogy can be seen in the appendix. These sections were made in the laboratory of the Geosciences Department of the National University of Colombia. The geological map presented is the integration of the mapping work of the authors and also the group of students of the last semester of Geology in a field course of the Universidad Nacional.

RESULTS

Petrography

First, a brief description of the rocks will be presented, followed by the microscopic features. Metamorphic rocks are mostly hornblende - garnet - zoisite - clinozoisite ± muscovite ± chlorite ± graphite schists. Some hornblende rich schists grade into amphibolites. A couple of igneous rock bodies were observed in the section: granodiorites, composed of quartz, plagioclase, K-feldspar, biotite and chlorite, and a tonalite that crops out at the easternmost

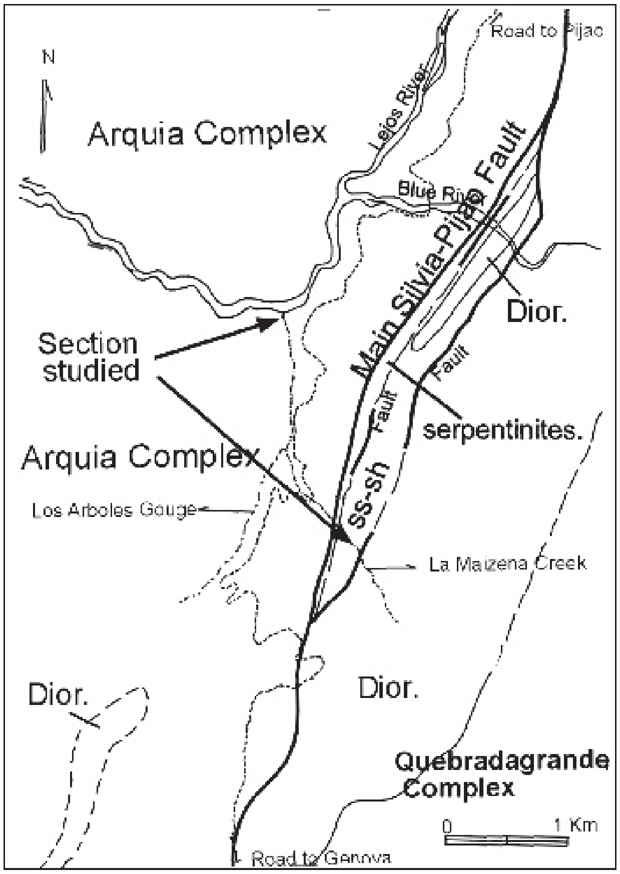


Fig. 2. Regional geologic map of the neighbouring areas to the "Quebrada la Maizena". Dior = igneous rocks mostly granodiorites. SS-Sh = sandstones and shale lenticular bodies of the Quebradagrande Complex. These sedimentary bodies as well as the serpentinized dunites are all emplaced along the main trace of the Silvia-Pijao Fault.

part of the section composed mainly of plagioclase, chlorite, quartz, carbonates and opaques. Various sedimentary rocks are present, mostly sandstones with calcareous and muddy matrix interbedded with mudstones and calcareous mudstones.

Structural geology

The regional orientation data is shown in Fig. 3. Data for metamorphic foliation (Fig. 4a) shows that the average strike of the foliation varies from azimuth 0° to 40°. Most of the deformational features are related to meter-scale thrust faults systems (duplexes and imbricates). Data from faults and their relative movement are shown in Fig. 4b. Thrust planes mostly trend 0°-45° (azimuth), dipping to the east and in less number to the west from low to high angle reverse faults (Fig. 5). Some low angle thrusts show striae indicating dip slip movement. Higher angle reverse faults show oblique dextral and siniestral components of movement. Contacts between different types of schists and between schists and serpentinites and schists or serpentinites with sedimentary rocks are all subparallel with azimuth 10°-35°. Most of high angle and vertical faults strike mainly in a NW-SE and SW-NE directions. It is important to note that about 5 kilometers north of this locality, along the main trace of the Silvia-Pijao Fault, some slices of sedimentary rocks are present. These rocks trend approximately N-S, dip about 55° to the east and are bounded by faults. A more complete description of these rocks and their structural attributes can be seen in Mojica et al. (2001).

Deformation structures

The objective of this section is to improve the understanding of the deformation mechanisms at microscopic level and to arrive to some assumptions about the deformation conditions of rocks. Such microstructures are presented next (some of them are shown in Fig. 6).

In quartz: undulose, patchy and sweeping extinction, deformation bands, inclusion trails, deformation lamellae, pressure solution, microfractures and lattice preferred orientation (rare). In feldspars (plagioclases): undulose and patchy extinction. In addition to Carlsbad and Albite growth twins, mechanical twins, bending, kinking, microcracking, pressure solution and compositional zoning also occur. In micas: mostly bending, microcracking and kinking. In hornblendes: undulated extinction, microcracking, and alteration to micas. In olivines: microfracturing and serpentinization. In carbonates (calcite): twins (mostly type I), pressure solution, veining and microcracking. Few samples also show superimposed metamorphic foliation when observed at microscope scale suggesting more than one deformational phase. There is also presence of inclusion trails and wrapped foliation around garnet porphyroblasts, both of which suggests that garnets are mostly syn- or pre-tectonic.

Fault rocks

Most fault rocks show cataclastic textures. Fault rocks range from poorly developed mylonites (protomylonites) to crush microbreccias, fault breccia, fault gouge and foliated gouge (Fig. 7). Fault rocks seem derived from the adjacent host rocks. The thickness of these rocks are variable and sometimes not easy to define. Highly deformed brittle zones commonly show numerous thrust faults. These zones may vary from 1 to 15 meters in thickness. However, microscopically, the deformation is clearly partitioned into

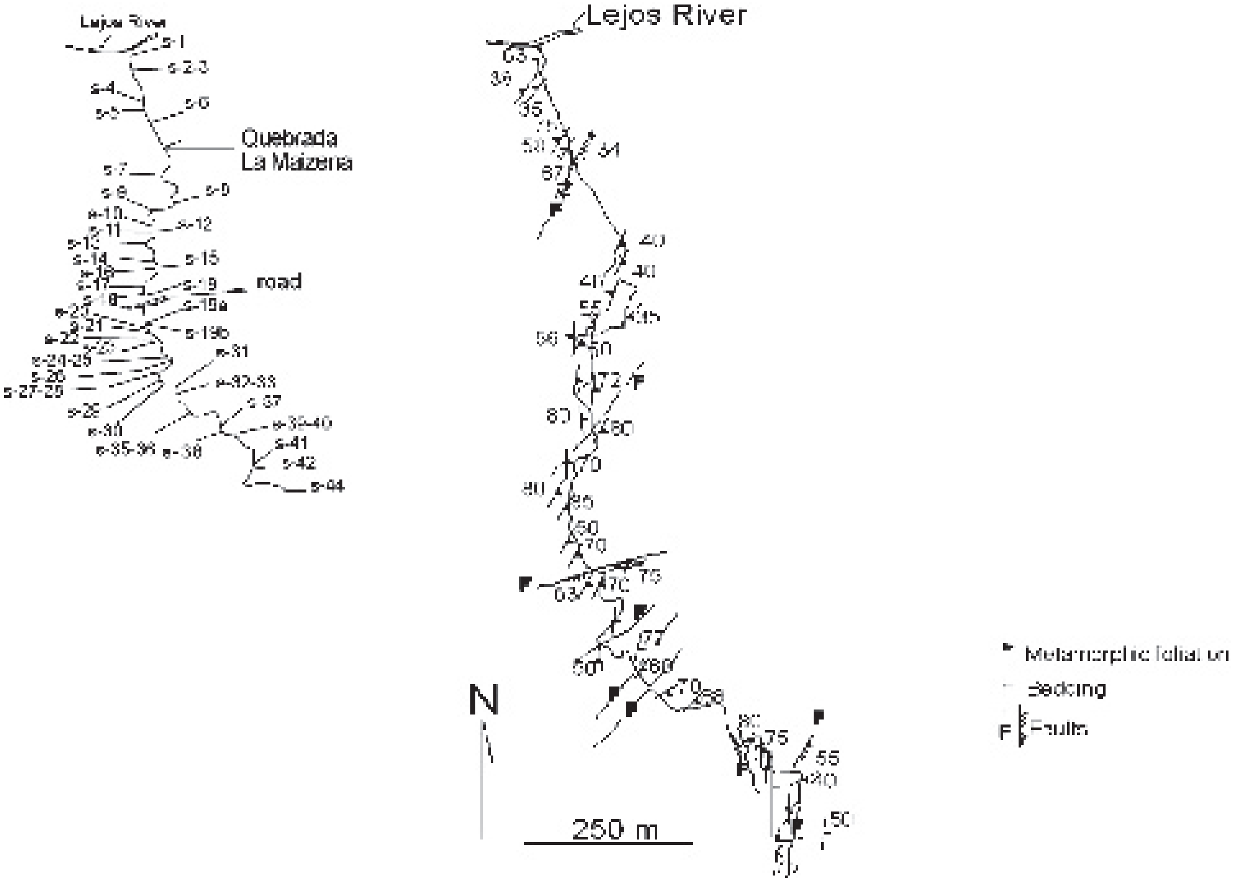


Fig. 3. Section of the lower portion of the “Quebrada la Maizena” with location of thin section samples. To the right, structural data obtained along the section. Most of data indicates east dipping structures, including faults and metamorphic foliation.

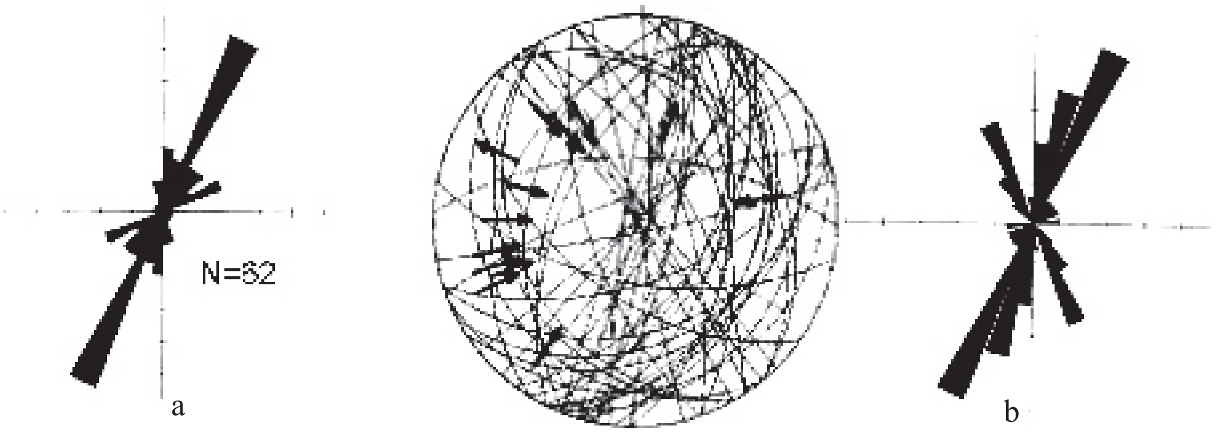


Fig. 4. Stereonets and rose diagrams of metamorphic foliation and fault orientations. A=main metamorphic foliations, B=fault planes. Arrows represent the orientation of slickensides and therefore their relative movements.

minor domains of microfault seams and less deformed or intact rock. These minor deformation domains also occur at milimeter scale. A completely objective measurement of individual fault thickness is difficult to establish because sampling has not been done along the whole fault zone and the character of deformation is not always obvious with the naked eye. Therefore, only rough estimations can be made. Determination of fault zones in the field (at outcrop scale) was usually done by a combination of different criteria such as presence of discrete faults, edge shaped blocks, eye-like structures, flow like texture, cataclastic texture, tectonic foliation related to thrusts and high angle reverse faults, microfolding (chevron and recumbent types), highly fractured rocks, development of breccias and gouge. At microscopic scale the structures indicative of shearing locate parallel, subparallel and at angle to the foliation, as previously noted.

DISCUSSION OF RESULTS

Data on foliations from the studied fault zone and the surrounding areas show mainly an eastward dip. Fault orientation data also indicate mostly west verging (easterly dipping) thrust fault systems. Foliation orientations are mostly parallel and subparallel to the average fault strike of the area. The trend following an azimuth of 0°-45° is the more common fault orientation and correlates with most previously mapped structures. However, fault trend orientations vary more than that of the metamorphic foliation. Cleavage also shows a wide range of values explained here as local disturbances of the main trend due to the effect of localized faulting. One clear example of this is the cleavage oriented 070°-090°.

Fault rocks provide evidence of several deformation events in the geological history of the Silvia-Pijao Fault. Some subparallel faults crosscut other less developed fault systems with different orientations. At a more regional scale NE thrust faults and high angle and subvertical faults oriented E-W or NW can be interpreted as formed by differently oriented brittle tectonic events. Kinematic indicators obtained from striae suggest different stress vectors. Indicators show a variety of senses of movement from normal faulting to reverse dip slip and oblique slip with components of strike-slip movement (Fig. 4). A regional compression from W-E to NW-SE can explain some of the most important families of faults, in particular thrust faults. The presence of high angle faults with striae showing normal dip slip is more problematic and differently oriented stress directions seem to be required. The lack of detailed information about these family of faults do not allow relating them to a particular tectonic event, either compressive (as a folded thrust) or extensive. The strike slip component of movement in some of the faults can be explained under the same stress orientations suggested for thrust faults. However, the presence of dextral and sinestral strike slip components suggest a probable shift of the compresssive stress orientations.

There is also presence of serpentinized rocks along some fault planes. The continuity of these bodies is not easy to follow; however, when constrained in several locations it is possible to suggest a lenticular geometry. Because of the nature and strength of serpentinite minerals it may be suggested that these bodies may control the localization of deformation.

Graphite-rich rocks are found in the Arquía Complex, but they are spatially related to fault rocks in the main shear zones (Fig. 8). Graphite is also present as inclusions in porphyroblasts. The presence of graphite enrichment in major fault zones, also as graphite gouge, is still enigmatic. Some hipothetical possibilities are: the fault zone obtained the graphite somewhere at depth and transported it to the surface along the fault plane, or that graphitic rich layers formed by metamorphic growth during deformation, providing a mechanically weaker rheology more feasible to be used to accommodate strain. In this case the high concentration of graphite could have been the result of dissolution of accompanying minerals redeposited in the shear zones as quartz, therefore generating a silica enrichment fault zone. The low strength of the graphite may be indicative of a strain-softened fault and may have an important role in strain partitioning where it is present. It also may indicate that these softened fault zones are the best candidates to be easily reactivated. However, some care is needed when seein graphitic rocks. In addition to their association to shear zones and quartz enrichments, it shows penetrative tectonic foliation which decreases away from the shear zone. Because of the graphite ductility, the rock may show ductile structures with contorted graphite laminae generating a texture that may be confused with a plastically deformed rock. With a lack of record of crystal plasticity and recovery these foliated cataclasites may be formed by brittle processes.

Micro and mesoscale structures and fault reactivation

Breccia, microbreccia, gouge and microfracturing indicate that the main mechanisms of deformation were cataclastic flow and grain sliding. Discrete microcataclastic zones affect mostly quartz. Microfaulting, cataclasis and grain sliding also affected micas, hornblendes and olivines. Along the section there is a distinction between localized shear zones and the much less deformed, or intact, rocks between them. Therefore, it is possible to suggest that the fault zone represents deformation partitioned along several minor fault zones separated by rocks considerably

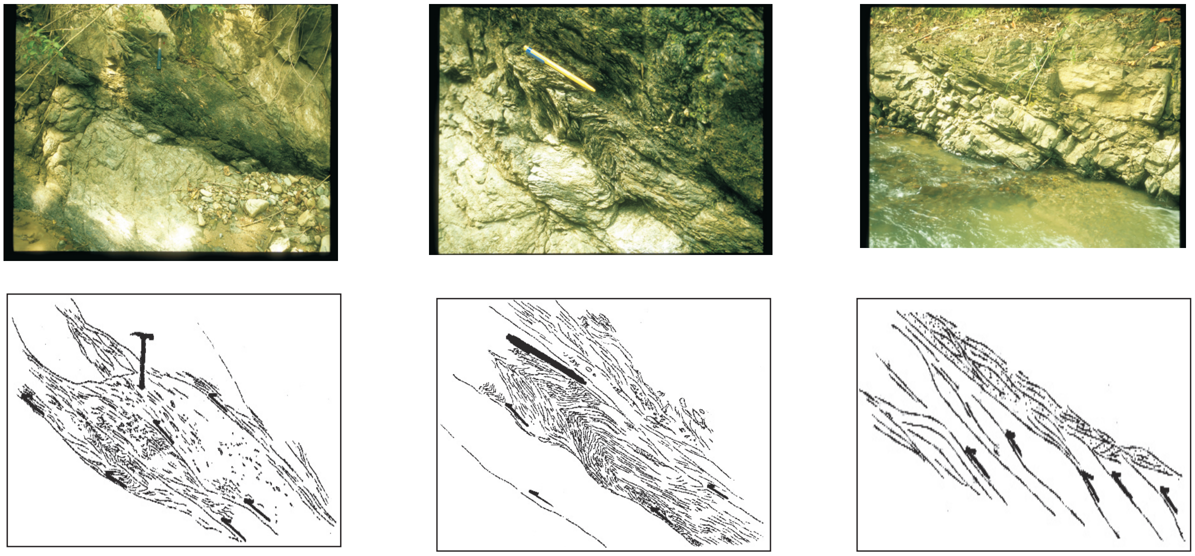


Fig. 5. Some of the most common brittle structures are represented by complex duplex thrust systems (a, b,and c). Coarser lines are the main fault traces. Arrows indicate the sense of displacement. In some of these faults oblique movement was recorded. The dotted patterns indicate the presence of gouge material along several fault planes. See pencil and hammer for scale. Width of view in c is 4 m. Views toward the north.

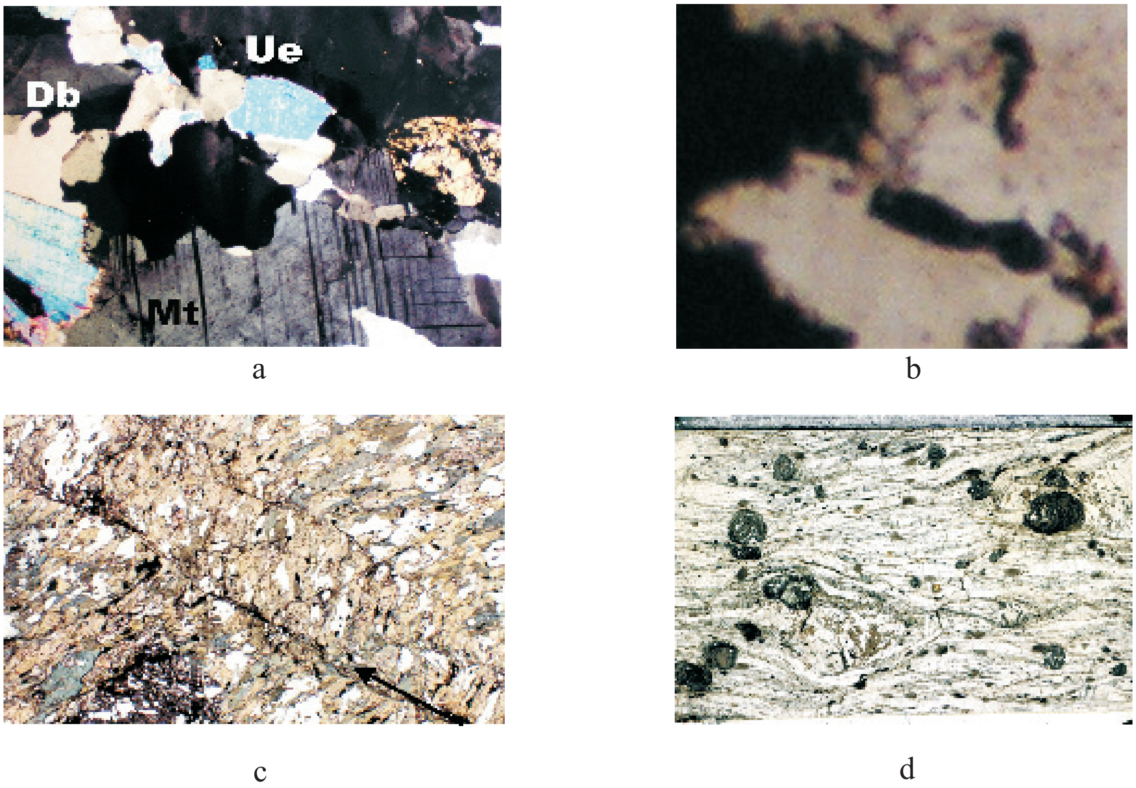


Fig. 6. Some microstructures observed in thin sections: a) mechanical twinning (Mt) in plagioclases, undulose extinction (Ue) and deformational bands (Db) in quartz, width of view 5mm; b) pressure solution bands in carbonates, width of view 5mm; c) superimposed deformation in amphibole schists, width of view 1 cm; d) garnet porphyroblasts wrapped by the metamorphic foliation, width of view 4 cm.

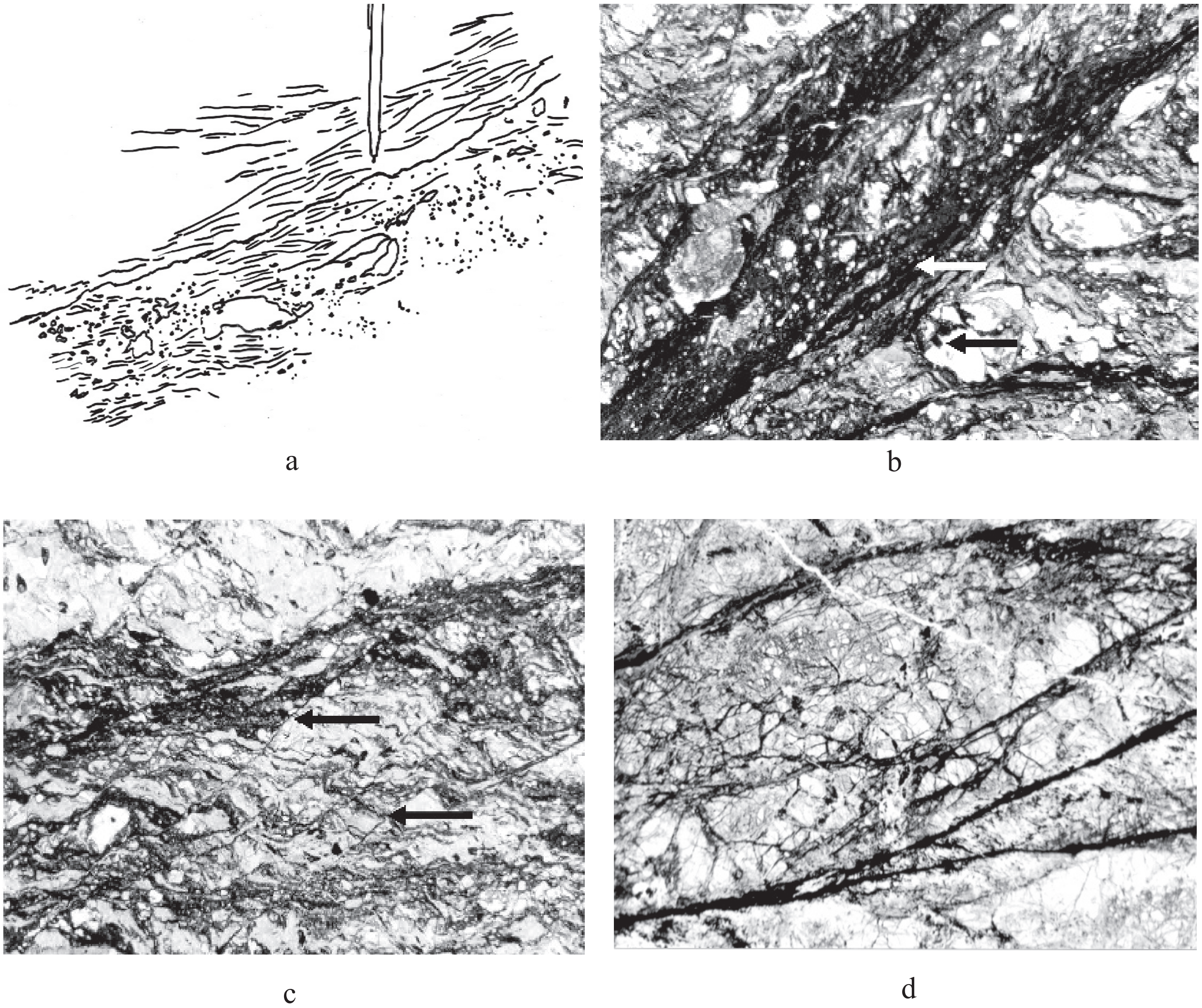


Fig. 7. Fault related structures at different scales: a) breccias (B) with gouge in the contact pointed by the pen (view to the S) b) microbreccias (see white arrow), c) microfaults displacing gouge seams (see black arrows) and d) microfaulting of serpentinized dunite. In (a) see pen for scale, in (b), (c) and (d) width of view is 5 mm.

less deformed. An anastomosing geometry is present at outcrop and microscopic scale. In highly silicified rocks quartz is precipitated as veins cutting the metamorphic foliation, therefore postdating the metamorphic events. Chlorite and muscovite are mostly parallel to the main foliation, however, they are mostly filling microsheared zones indicating earlier crystallization. In some thin sections there is clear presence of a secondary foliation characterized by planes, not homogeneously at a high angle to the main foliation.

The most important metamorphic assemblage is hornblende-garnet-zoisite muscovite and chlorite. These minerals are formed in low to medium metamorphic grade conditions. Rocks with no amphiboles are also present exhibiting a paragenesis of lower temperature. Amphibolite to greenschist facies are therefore interpreted.

There is also evidence of discrete plastic deformation in rocks as observed in thin section (Fig. 9a). Presence of grain boundary recrystallization in quartz, and, to a lesser extent in plagioclase, and other structures such as undulatory, patchy and sweeping extinction and mechanical twins in plagioclase (Fig. 6a) indicate that deformation occurred at a deeper level in the crust, very likely at very low grade metamorphic conditions (< 350 ° C). It contrasts with shallower conditions inferred from brittle deformation as shown by thrust and high angle faults and presence of

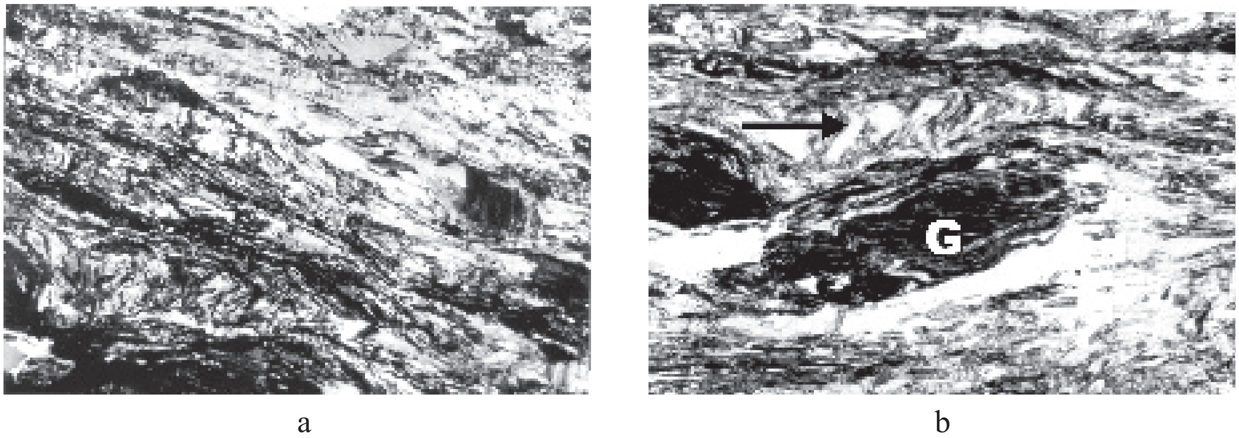
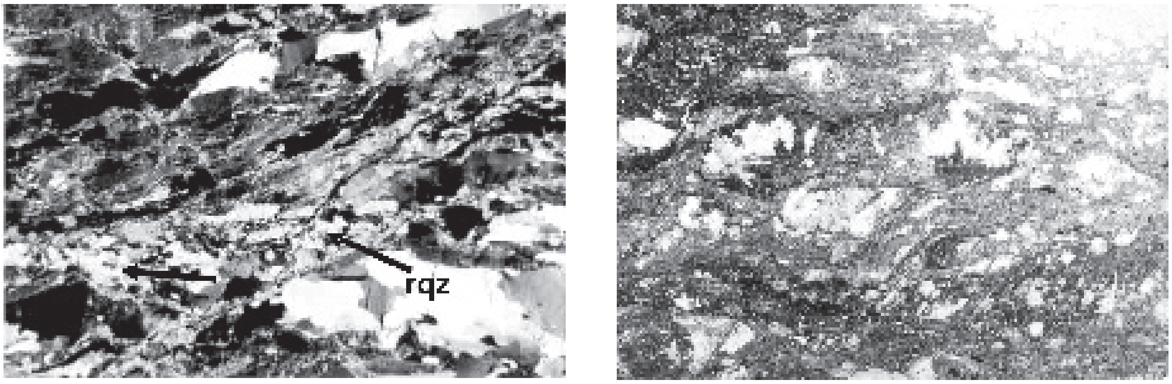


Fig. 8. Microscopic deformation of graphite. Note in (a) the gradual variation of graphite (dark laminae) towards the non-graphitic rock; (b) graphite (G) in packages and also fine and highly contorted laminae (black arrow). Graphitic gouge with striated planes is common in these faults. Width of view for (a) and (b) is 5 mm.

both consolidated and unconsolidated breccias and gouge. In addition, the presence of serpentinized ultrabasic rocks along the trend of the Silvia-Pijao Fault suggest transport from deeper levels to the surface. The approximate parallelism between brittle faults and anastomosed and parallel-to-foliation recrystallization in a number of samples suggest that deformation has been taken place along the fault zone at different levels in the crust.

It is also important to note that fault zones exhibit different characteristics. Some show cataclastic textures with or without development of gouge. Faults with different degrees of silicification are also present. These silicified faults usually show a well developed cataclastic deformation implying probable larger displacements. In some of these quartz-enriched fault zones mylonitic textures were also observed together with Graphite (Fig. 9b). As discussed above, foliated cataclasites with graphite may have formed just by brittle processes; however the presence of small recrystallized grains to the margins of some of the quartz porphyroclasts suggest brittle-ductile deformation. These zones of plastic deformation are discrete and relatively rare in the area. It is likely that during field work many of these zones had been missed. Ultimately, thin section analysis provide the arguments for the interpretation. Field observation may or may not be sufficient to determine the presence of crystal plastic mechanisms. Along fault zones located in serpentinic rocks mylonitic textures were not observed. In general, an anastomosing fashion of shear zones is observed at microscopic and outcrop scales and it is suggested to be present at regional scale.

Even though field observations suggest complex phases of deformation through time, still to be fully understood, an important number of evidences of fault reactivation has been shown in this work. These observations are compatible with those proposed to the RFZ in different locations by different authors as far as the kinematic evolution of the fault zone. Paleomagnetic analysis of igneous bodies associated to the RFZ are presented by MacDonald et al. (1996) and studies related to the sense of movement of the fault zone and recent activity have been carried out by Toussaint & Restrepo (1976), Ego & Sebrier (1995), Arias (1981), Sierra (1994) and MacDonald et al. (1996). The latter authors interpreted rotation of igneous rocks closely related to the RFZ. Their interpretation show subvertical and subhorizontal axes of rotation for lenticular rock masses of tertiary intrusions along the related fault zones. Sierra (1994) interpreted two senses of slip for the RFZ since late Miocene to Pleistocene, right and left lateral movements were constrained based on paleomagnetic studies and also based on some related pull apart basins such as the Irra basin. Milward et al. (1984) consider the Diabase Group (Western Cordillera) to be formed not as a volcanic arc but as an extensive oceanic flood basalt, accreted to the continent along the RFZ. Many other authors also consider the RFZ as a Terrane boundary (Etayo et al. 1983, Restrepo & Toussaint 1973, Aspden & McCourt 1986) and therefore with particular structural associations and probable suture development. De Souza et al. (1984), interpret the emplacement of ophiolites along the RFZ. De Souza et al. (1984), Nivia (1987), McCourt (1984), Milward et al. (1984), and Spadea et al. (1987) have carried petrographic and geochemical analysis of rocks at both sides of the RFZ implying a complex fault zone evolution. The reported high pressure rocks in other areas (located further south in the Central Cordillera) such as glaucophane schists (Feininger 1982, McCourt & Feininger 1984) also suggest a complex history of movement along some of the faults of the RFZ. Vergara



a b

Fig. 9. In a) note bimodal quartz families: big quartz ribbons (QR) with undulose extinction and tiny recrystallized quartz grains (rqz) in irregular bands (See black arrows); width of view 5 mm. In b) (scanned thin section) observe the texture strongly controlled by the ductility of graphite; width of view 4 cm. This sample is interpreted to have deformed by brittle-ductile processes inferred from small recrystallized quartz grains to the margins of some of the larger polymineral quartz porphyroclasts.

et al. (2001) considers that some of the faults associated to the Romeral Fault System (including the Silvia-Pijao Fault) show evidences of neotectonic activity and were probably responsible for the Quindio seismic event of January 1999. As can be seen, all these previous works directly or indirectly indicate the numerous ways the fault zone could have been formed and undertake reactivation.

CONCLUSIONS

The Silvia-Pijao Fault Zone records a long history of deformation. A complex brittle deformation history can be interpreted to have occurred along the fault zone. Microfracturing and grain sliding are the most important mechanisms of deformation of cataclastic rocks. Outcrop scale structures such as duplexes and imbricates, strike-slip and normal faults with dip and oblique components of movement, tectonic foliation, arying fault cross-cutting relationships and presence of sedimentary slices and ultrabasic serpentinized bodies along the fault zone are the record of several brittle deformational phases. In addition, a much less evident and older localized plastic deformation can be identified, characterized by discrete zones of mylonitization. The superimposition of different multi-directional brittle faulting events over an older localized plastic deformation and the interpreted neotectonic activity of this fault (Vergara et al. 2001) strongly suggest that this fault zone is a long-lived structure, with a record of numerous reactivation events through time. The presence of serpentinized ultramafic bodies and abundant graphite in the major fault zones strongly suggest a lithological control on the localization of faulting.

Very little is known about how stresses and strain are accommodated along the different faults that constitute the Romeral Fault Zone. Works that attempt to elucidate the history of evolution of fault rocks associated to the faults of the RFZ are needed to constrain some of the controversies about the timing of deformation, kinematic evolution, fault zone attitude and sense of shear through time, among others.

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Appendix

Sample	Clasification	Minerals
mc-1	Limestone.	Cal, qtz, polymineral agregates.
mc-2	Horn schist.	Horn, qtz, chl, plag, epi, zois, gar, zir and ox(black and redish orange).
mc-3	Horn schist.	Horn, chl, qtz, epi, zir and ox.
mc-4	Horn-gar schist.	Horn, chl, qtz, plag, gar, zois and clin, musc and zir. Also ox.
mc-5	Horn schists.	Horn, qtz, chl, musc, zois-clin (zoned), carb (cal), ox in carb, zir, and chl.
mc-6	Horn-gar schists.	Horn, qtz, gars, zois-clin (zoned), chl, ox, carb, zir and pyr.
mc-7	Horn-gar schists.	Horn, qtz, chl, gars, zois
mc-8	Cataclasite (from horn schist).	Qtz, horn, zois, clin, chl, few plag, zir.
mc-9	Cataclasite. Mylonite seams?	Qtz, epi, zois, clin, chl, polycrystalline grains, horn and zir.
mc-10	Horn schist.	Horn, qtz, gars, carb. Zois, clin (zoned), chl and zir.
mc-11	Horn schist.	Qtz, horn, trem, plag, chl, zois and clin, and zir .
mc-12	Horn schist.	Horn,chl, qtz, plag, zois, musc, zir.
mc-13	Horn-schist.	Horn, qtz, plag, zois, chl, zir, musc.
mc-14	Chl schist.	Plag, qtz, chl,zois,musc, and zir.
mc-16	Chl schist.	Plag, qtz, chl, musc, zois, clin (zoned), graph, zir, ox and ti.
mc-17	Cataclasite.	Qtz, graph, musc, gar, chl, and tiny zir.
mc-18	Quartz-chloritic schist.	Qtz, chl, plag, carb (cal), zois, clin, abundant zir and pyr.
mc-19 a	Cataclasite of horn schist.	Qtz, plag, chl, horn, zois, clin and zir.
mc-19 b	Zois schist.	Qtz, chl, zoisite, few plag, horn, musc, tit and rut.
mc-20	Horn schist.	Horn, musc, chl and very few qtz, and plag.
mc-21	Qtz -musc schist?..mylonite?	Qtz, musc, chl, zir, ox, graph, gars, and clin.
mc-22	Horn schist.	Horn, chl, qtz, plag, clin, tit, rut and zir.
mc-23	Serp schist??	Act, serp, carb, chl.
mc-24	Acti schist?	Act, serp, few horn, tit and rut.
mc-25	Qtz -musc, gar,epi schist.	Qtz, musc, chl, clin, gar, tit, rut and plag.
mc-26	Horn schist.	Amph, musc, qtz, plag, gar, chl, clin.
mc-27	Amphibolite.	Horn, plag, gars, qtz, chl, clin.
mc-28	Gar amphibolite.	Horn (rich in Al), qtz, plag, horn, gar, carb, ox, carb, clin and zir.
mc-29	Gar-Amphibol schist.	Plag, qtz, horn, gar and zois, clin, carb, chl, ox, carb. Gar in the field.
mc-30	Gar, zoisite schist.	Gar, musc, plag, clin, serp and Fe-ox.
mc-31	Horn schist.	Horn, gar, qtz, plag, carb, rut.
mc-32	Musc-gar- schist.	Qtz, plag, gar, abundant musc, chl, zois, rut and tit.
mc-33	Act-trem schist.	Actinolite/tremolite, carb, chl.
mc-34	Granodiorite.	Qtz, plag, biotite and chl.
mc-35.	Horn-epi-chl schist.	Qtz, chl, horn, plag, clin, rut, ox and carb.
mc-36	Gar- musc –schist.	Gar, musc, qtz, clin, ox (redish ox).
mc-37	Horn- gar-schist.	Horn, chl, clin, qtz, plag, rut.
mc-38	Horn schist.	Qtz, musc, horn, chl, and op.
mc-39	Horn, gar schist.	Qtz, horn, plag, chl, carb, musc, gar, clin, rut.
mc-40	Serpentinized dunite/olivinite.	Oliv, serp, and chl.
mc-41	Muddy sandstone.	Qtz, clay, carb, ox, opaques, abundant in the matrix.
mc-42	Sand with muddy carb.	Qtz, qtz aggregates, carb.
mc-43	Calc. mudstones.	Chl, Carb, chls, qtz, qtz aggregates, very fine mud.

Qtz= quartz, Plag=plagiolclase, Horn=hornblende, Chl=chlorite, Mus=muscovite, Gar=garnet, Clin=clinozoisite, Graph= graphite, Act=actinolite, Car=carbonates, Trem= tremolite, Epi=epidote, Oliv=olivine, Serp=serpentinite, Ti=titanite, Rut=rutile, Zir=Zircon, Ox=oxides, Op=opaques.