U.S. Department of Labor

Mine Safety and Health Administration
Pittsburgh Safety & Health Technology Center
P.O. Box 18233
Pittsburgh, PA 15236
Roof Control Division

06AA23(a)

August 31, 2006

MEMORANDUM FOR RICHARD A. GATES
District Manager, CMS&H District 11

THROUGH: KELVIN K. WU
Acting Chief, Pittsburgh Safety and Health Technology Center

M. TERRY HOCH
Chief, Roof Control Division

FROM: SANDIN E. PHILLIPSON
Geologist, Roof Control Division

SUBJECT: Evaluation of Features at Wolf Run Coal Company, Sago Mine, MSHA I. D. No. 46-08791

Observations

As requested by the MSHA Accident Investigation Team (Sago), observations of geologic features were performed in the formerly sealed 2nd Left Mains, in the vicinity of spad 4010 on February 21, 2006. The purpose of the observations was to evaluate and document two linear features in the mine roof in the vicinity of spad 4010. Observations were restricted to the #5, #6, and #7 Entries, between the 1st and 3rd Crosscut from the #1 Entry of the Main. The 2nd Left Mains are developed at an approximate 60° angle from the left side of the Mains, such that the first crosscut in the 2nd Left Main in the #6 Entry is actually the third crosscut in the #1 Entry.

Observations began just inby spad 4010, in the #6 Entry, and proceeded down-grade into the next, benched intersection at spad 4047. The observation traverse proceeded east from spad 4010 into the #7 Entry through the intersection with spad 4011, and then inby along the benched #7 Entry for two crosscuts to the spad 4063 intersection. Observations continued in the unbenched crosscut between spads 4045 and 4047.

Detailed observations concluded just inby the spad 4010 intersection, where the two linear roof features were scrutinized. A similar feature was briefly examined in the neighboring #5 Entry, just inby the spad 4028 intersection.

The observation area is characterized by a variety of abundant structural geologic features and stress-related features. Abundant, very well developed joints were observed in the roof (Figure 1). The dominant joint set is oriented with a strike of N 85°E, and is characterized by nearly vertical joints that are spaced approximately 12-20 inches apart. Joints of this set were present across the entire observation area, from the spad 4010 intersection to the spad 4063 intersection, a distance of two crosscuts. Two minor, irregularly spaced sets of joints, oriented respectively at N 57°W and N 30°E, are aligned parallel to the trend of slickenside planes. A prominent slickenside plane that controlled a zone of buckled roof strata was oriented N 30°E, with a dip of 35° toward the southeast, and is located in the southeast corner of the spad 4047 intersection. A pair of slickenside planes, oriented N 67°W and dipping 50° NE, formed a linear, coffin-shaped roof cavity that trended through the spad 4045 intersection, crosscutting a wide, deep horizontal stress pot-out.

Figure 1. Very well developed joint set, characterized by N 85°E-striking joints spaced 12-20 inches apart. Photo taken in the crosscut between spads 4010 and 4011.

Horizontal stress pot-outs were common in the observed area, and were consistently oriented with a long axis aligned along a bearing of approximately N 5-7°E (Figure 2). Long-running cutters, localized at the intersection between the roof and rib, were consistently located along the west rib of the observed entries. In the #7 Entry, a long-running cutter left the rib and crossed through the spad 4063 intersection along a bearing of N 10°E.

Figure 2. Downward-buckled zone of thinly laminated shale represents a stress pot-out that follows a trend of approximately N 5-7°E. Other linear buckled zones of shale are aligned along the same bearing throughout the observed area.

Ground conditions were particularly degraded in the observed portion of the #7 Entry, with abundant stress pot-outs and cutters developed at the projected intersection of the mutually perpendicular slickenside planes.

Detailed observations concluded just inby the spad 4010 intersection, where a small scaffold was constructed to reach the roof and observe two linear features that were present (Figure 3). Each linear feature was characterized by a pair of parallel ridges that trended across the exposed flat plane of the roof. One pair of parallel ridges was oriented along a bearing of N 43°E, while the other pair of parallel ridges was oriented along a bearing of N 70°E. The parallel ridges were spaced approximately 2-3 inches apart, and protruded approximately ¼ inch below the flat roof horizon. The roof horizon is characterized by thinly laminated, muscovite-rich gray shale that in the immediate vicinity of the area hosts oval-shaped, downward-buckled stress pot-outs.

The parallel ridges are characterized by an irregular, rough texture, but are bounded by immediately adjacent patchy areas of approximately 5-10 cm^2 that represent a flat, smooth, slickenside plane that follows the base of the muscovite-rich gray shale (Figure 4). No part of the linear ridges appeared to extend upward into the thin shale layers of the roof, as indicated by a thin brow that intersected the edge of the linear features along the trend of a prominent stress cutter. The collection of a piece of the protruding ridge was attempted with a knife blade, but the ridge represents only a very thin (<1 mm) coating of slickensided shale, and scratching with the knife blade immediately exposed the overlying muscovite-rich gray shale above the thin coating. This resulted in the whitish streaks shown in Figure 5.

Figure 3. Two pairs of parallel ridges exposed on the underside of the shale roof, and disrupted where a shallow stress pot has broken out of the roof. No evidence of the linear features was found in the thin brow of the stress pot along the trend of the linear feature, indicating that it does not extend upward into the rock.

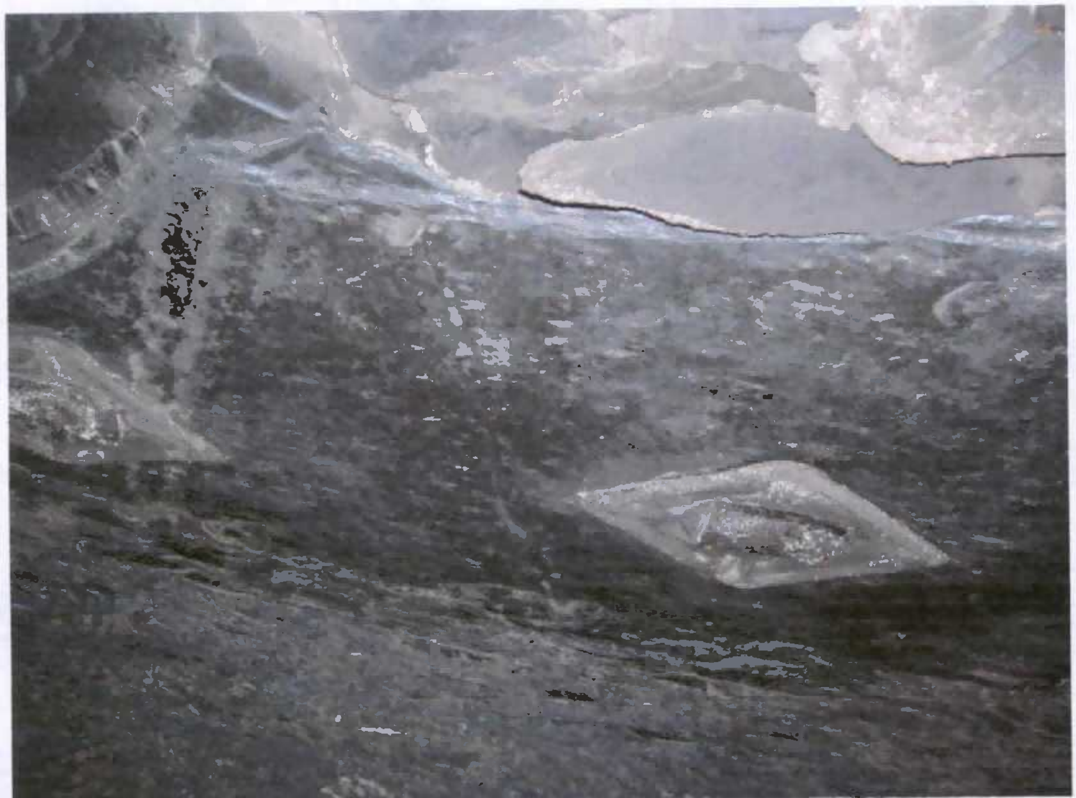

Figure 4. Two pairs of linear, parallel ridges exposed on the bottom surface of the gray shale. Center feature lies along a trend of N 70°E, forming an acute angle with the feature at left, which is oriented along a trend of N 43°E. There is no indication of the linear features extending above the thinly laminated immediate layer of the roof, as exposed in the thin brow formed by the stress pot-out.

Figure 5. Light brown linear streaks along the trend of the parallel linear ridges represent knife scratch marks from an attempt to collect fossil material. Location is the vicinity just inby the spad 4010 intersection. Twin parallel ridges pass beneath the embossed, square skin control plate.

Discussion

The purpose of the February 21st mine visit was to observe and identify two pairs of linear features located in the vicinity of spad 4010, in the 2nd Left Mains. Although there are abundant structural geologic discontinuities in the surrounding area, including joints and slickensided faults, the pair of linear features in question is not structural geologic features. Instead, the linear features observed just inby spad 4010 in the #6 Entry, and portrayed in Figures 3-5, represent the remnants of a pair of fossilized trees, with each linear feature representing the top, tangential edge of a single tree. The rough texture of the linear feature represents the trace fossil impression of the tree bark as preserved against the bottom layer of the overlying muscovite-rich gray shale, and the pair of parallel ridges represents compaction of the muscovite-rich gray shale downward around the formerly circular boundary of the tree trunk. Although the fossil tree was removed by mining the immediate shale roof, the linear features represent the expression of the top edge of the tree where it tangentially contacted the bottom of the bedding plane exposed in the shale roof.

If you should have any questions regarding this report, or if we can be of further assistance, please contact Sandin Phillipson at 304-547-2015.

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06AA23(c)

September 1, 2006

MEMORANDUM FOR RICHARD A. GATES
District Manager, CMS&H District 11

THROUGH: KELVIN K. WU
Acting Chief, Pittsburgh Safety and Health Technology Center

M. TERRY HOCH
Chief, Roof Control Division

FROM: SANDIN E. PHILLIPSON
Geologist, Roof Control Division

SUBJECT: Description of Features Observed in the Roof Inby Spad 4010, 2 Left Mains, in Wolf Run Mining Company, Sago Mine, MSHA I. D. No. 46-08791

Background

As requested by the Sago Accident Investigation Team, the author witnessed the extraction of a mine roof sample on March 1, 2006 by personnel from R. J. Lee consultants. The sample extraction area is located just inby spad 4010 (Figure 1) where two prominent features are located in the roof (Figure 2). The features generated interest because they are located in the area where the explosion in 2nd Left Mains is believed to have originated. Because the features were not recognized as being widespread, they were quickly referred to as "anomalies." Due to their location in the area interpreted as the explosion site, some parties speculated that the linear "anomalies" might represent the effects of lightning arcing across the mine roof. Although initial observations conducted by Roof Control Division (RCD) personnel on February 21, 2006 (RCD February 27, 2006 Draft Memo) indicate that the linear features represent compaction along the length of a tree fossil, consultants retained by the mine collected samples of the features in order to document any possible effects of lightning.

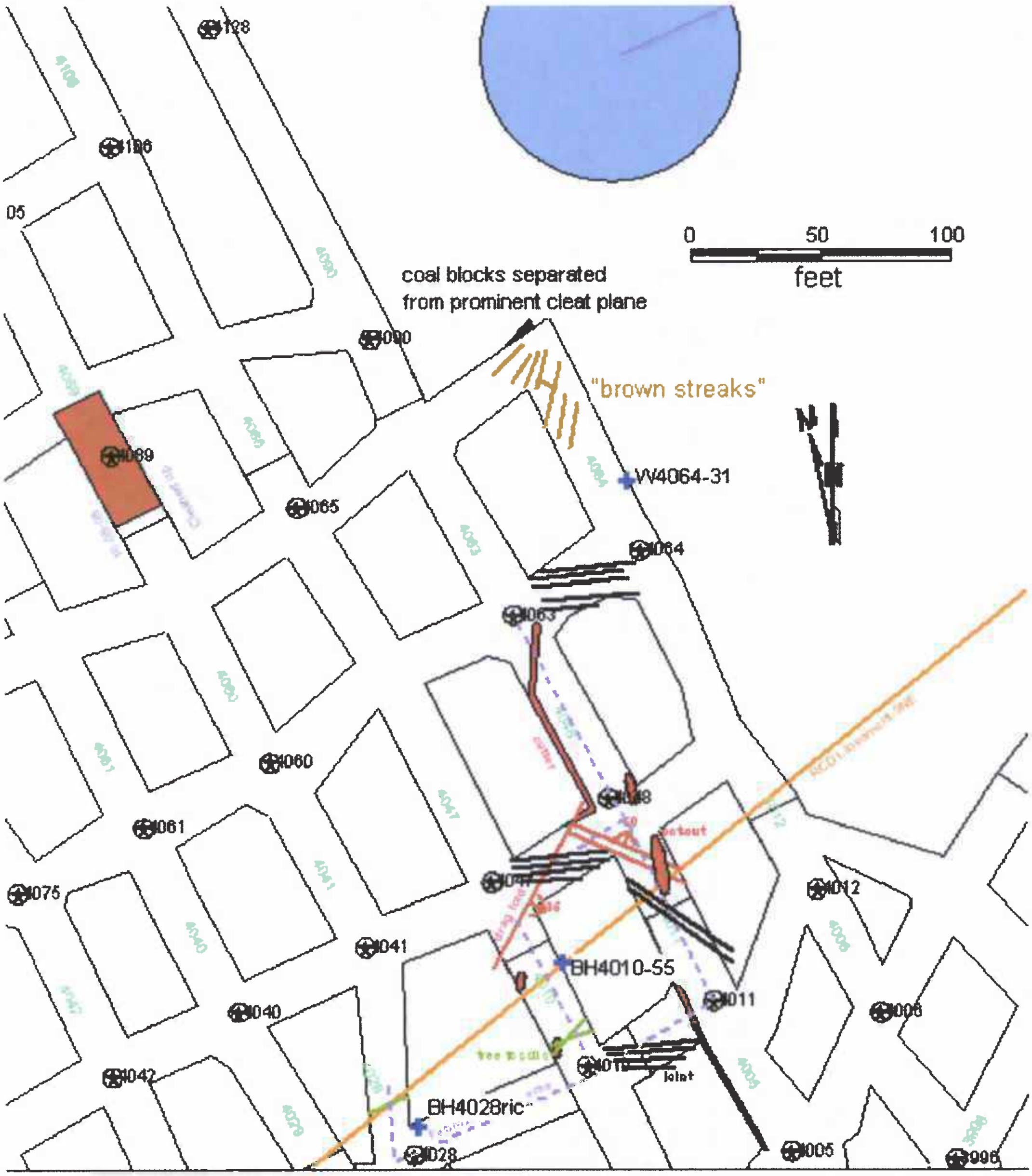

Figure 1. Map of geologic features in a portion of the 2nd Left Mains, showing results of mapping from February 21 and March 20, 2006. Sample collection area is centered on dark green features just inby spad 4010. Dashed purple line indicates February 21, 2006 observation traverse.

Figure 2. Two sets of paired, linear ridges define an acute angle in the roof horizon just inby spad 4010. R. J. Lee sample collection effort on March 1, 2006 extracted samples of this feature. In this photo, the linear feature is truncated by a shallow stress pot-out.

The effects of lightning have been documented in unconsolidated soil, loose sand, and solid rock. The preserved effects of lightning on rock and soil can form silica glass known as "fulgurite". Fulgurite has been found in soil and sand dunes, forming a small tunnel with walls of silica glass, presumably formed by high temperature melting and fusing of quartz sand grains (Figure 3). Other experiments documented on various websites indicate that fulgurite can be formed in any rock composition with sufficient voltage. The longest fulgurite tunnel was reportedly approximately 20 feet long, and a search of available literature suggests that the fulgurite tunnels are 2-3 inches in diameter. Photos available on websites indicate that the cylindrical, glass-walled tunnels undulate, twist, and turn, commonly branching or bifurcating through the unconsolidated soil material. Although lightning can affect solid rock, available observations indicate that fulgurites in rock are restricted to the top several feet of mountain peaks, and seldom penetrate more than a few inches into the rock. Lightning can magnetize iron minerals in rock outcrop, as observed by the author at a location in the Colorado Rocky Mountains.

Figure 3. Sample of fulgurite for sale on internet website, showing branching texture of bubbled silica glass.

Thus, visible effects of lightning on a rock would be expected to include the formation of silica glass or quartz grains that showed signs of partial melting or fusing. Glass, of which volcanic obsidian is an example, is very distinctive in the geological environment. Most geologically formed glass is associated with volcanism, in which high-temperature molten rock is frozen before crystals can nucleate and grow.

Methodology

The mine's consultants obtained four rectangular samples from the roof and retained three for testing. Samples were obtained using a battery operated "ripsaw" to define a rectangular cut sequence to delineate the sample. After a notch was cut to provide working room, a wide, flat chisel was used to force separation along a delamination plane along bedding to remove the sample from the roof (Figure 4).

Figure 4. Shallow rectangular box remains where samples of the linear "anomaly" were retrieved on April 6, 2006 (center). Samples were collected from the same "anomaly" on March 1, 2006 by R. J. Lee as indicated by shallow box located at right of photo. Samples 3045477 and 3045475 were retrieved from the box on the right side of the field of view.

Splits of the three samples obtained by R. J. Lee were passed to MSHA on March 13, 2006, and obtained by the author on March 16, 2006. Two of the samples were cut with a water-cooled, diamond blade rock saw at the Approval and Certification Center (A&CC) to obtain a cross section through the area where the linear feature appears (Figure 4). The cross section slice was annotated with five rectangular blocks to be prepared for thin sections. Locations of the rectangular blocks were marked on the mating surface of the original sample split (Figure 5). Each outlined block was then sawed from the cross section slice to define an individual sample (Figure 6). The chips were then sent via FedEx to Spectrum Petrographics in Vancouver, Washington, to prepare thin sections of the samples. Thin sections are slices of the rock that are ground so thin that light can pass through the sample, while glued to a microscope slide so that microscopic textures and details can be documented. The completed thin sections were received on April 7, 2006 (Figure 7).

Figure 5. Split of Sample 3045477 obtained by R. J. Lee on March 1, 2006 at A&CC, showing cross section across the linear feature observed inby spad 4010, 2nd Left Mains. The work shown was performed at the Approval and Certification Center.

Figure 6. Cross section slice from Sample 3045477 (top pair) and Sample 3045475 (bottom pair) further separated into individual chips ready to be made into thin sections for detailed study. The work shown was performed at the Approval and Certification Center.

Figure 7. Completed thin sections (glass microscope slides) and original sample chips prepared at A&CC returned by Spectrum Petrographics laboratory on April 7, 2006.

Summary of Rock Texture Observations

Subsequent to sample preparation at A&CC, the chip from Sample 3045475 was observed to exhibit a striking texture. The sample hosts a very thin layer of black, coal-like material that appears to represent carbonized (coalified) plant bark, as indicated by a series of parallel lines that are similar to the cellulose of plant fibers (Figure 8). The carbonized, fossilized plant material is located at the core of the twin, parallel linear ridges that trend across the roof of the area inby spad 4010 in 2nd Left Mains.

The thin sections of Samples 3045477 and 3045475 were studied with a Meiji 9400 Series polarizing light microscope at viewing scales of 40X to 100X.

The samples of shale are classified based on grains size and bedding spacing as "laminated siltstone" according to Potter's 1980 textural classification of shales. Because all six samples were collected from the same sedimentary horizon, within approximately 2 inches from the mine roof, they are characterized by very similar textures. Each of the six samples is characterized by a matrix composed of very fine-grained (0.005-0.2 mm) muscovite lathes, which are randomly oriented but arranged in thin bedding layers. Contacts between adjacent bedding layers are gradational, defined by different grain sizes or mineral contents. The very fine-grained, muscovite-dominated layers host approximately 8-12% angular quartz grains, which are approximately 0.01 mm in diameter and isolated by the surrounding matrix. Coarser-grained layers are dominated by angular quartz grains, which are approximately 0.1 mm in diameter and touch along tangential contacts to leave angular interstices that are filled with finer-grained muscovite. The very finest-grained layers host very fine-grained, clay sized (<0.003 mm) muscovite with no quartz, and represent planes of preferential weakness along which delamination preferentially occurs.

Textures in all samples are very similar, characterized by muscovite-dominated layers corresponding to alternating grain sizes of "fine silt" and "medium silt". This material represents approximately 80% of the layers in each small, rectangular thin section. The remaining approximately 20% of layers are represented by "very fine quartz sand". Bedding layers are generally of uniform thickness, remaining parallel in relation to the bedding parting that represented the mine roof horizon. One notable exception to this is represented by Sample 3045477-4, which hosts a series of thin, discontinuous iron hydroxide stringers that suddenly ramp up away from the mine roof horizon, such that the stringers become closer together as they rise into the roof. This texture is characteristic of compaction of unconsolidated sediments around obdurate objects, and is referred to as draping. The parallel bands of "very fine sand" quartz, located approximately 5 mm higher in the section, exhibit the same rising at the same point on the traverse. The area defined by the compaction texture is at the margin of one of the two protruding ridges, which define the "linear anomaly" observed in the mine roof just inby spad 4010. The presence of the compaction texture, combined with the thin layer of carbonized plant material, suggest that the twin linear ridges observed in the mine roof represent local compaction of the muscovite-rich laminated siltstone immediate roof around a linear tree trunk. No silica glass or magnetite was observed in any of the thin sections, and no textural evidence was observed to indicate that grains have been fused together.

Figure 8. Enlarged view of a small, rectangular sample chip prior to being sent for thin section preparation. This piece of Sample 3045475 exhibits a black area that represents carbonized fossil plant bark. Parallel lines are interpreted to represent cellulose plant fiber. The pair of linear features observed inby spad 4010 in 2nd Left Mains is cored by this carbonized fossil material. The sample is approximately 7/8 inch wide x 1¾ inches long.

Appendix of Thin Section Descriptions

Sample 3045477-1 (Figures 9 and 10)

The sample is composed of fine laminations of randomly oriented, fine-grained, ragged muscovite lathes. Although muscovite lathes appear randomly oriented in detail, partings between some laminations are sharp and distinct. Most micaceous bedding layers host isolated grains of angular quartz that are diffusely scattered parallel to bedding laminations. Individual quartz grains are commonly surrounded by a thin, diffuse halo of very fine-grained muscovite that may represent diagenetic sericitization. Locally, angular quartz grains occur in sufficient quantity to define quartz-dominated interbeds that are parallel to bedding laminations. Quartz grains in the discontinuous interbeds touch along tangential contacts, and individual grains remain partially surrounded by a matrix of fine-grained muscovite lathes that are randomly oriented. Laminations defined by very fine-grained muscovite commonly represent preferential delamination horizons.

The sample contains approximately 15% quartz, which ranges in size from 0.01 mm ("fine silt") to 0.1 mm ("very fine sand"). The remaining approximately 85% of rock volume is represented by muscovite, which ranges in size from 0.005 mm ("fine silt") to 0.04 mm ("medium silt"). Based on the size of grains, thickness and nature of bedding layers, and content of clay-sized material, the shale sample is classified as a muscovite-rich laminated siltstone.

Textures suggest a low degree of compaction because individual mineral grain long axes are not strongly aligned with bedding planes. Long axes of angular quartz grains commonly form an obtuse angle with bedding laminations, indicating that grains were not forced to rotate. Although bedding textures are commonly diffuse, thin, discontinuous stringers of iron hydroxide are aligned parallel to bedding and highlight laminations. Despite the presence of iron hydroxide, no magnetism is present, as tested with a small, powerful magnet that is weakly attracted to samples with as little as <1% magnetite.

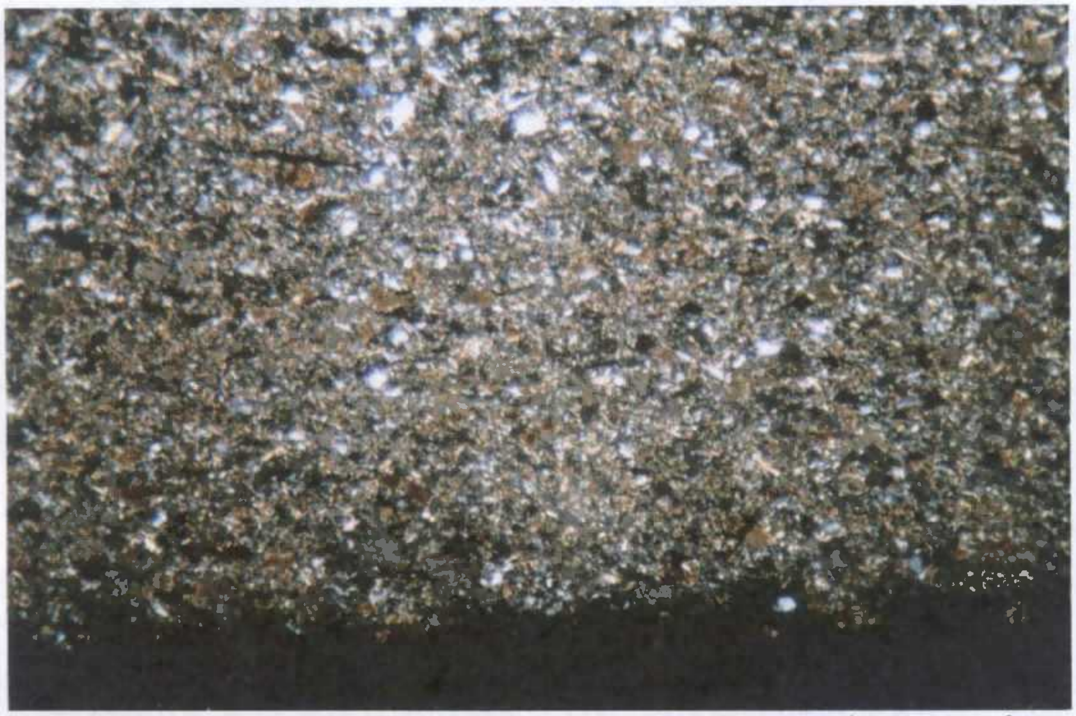

Figure 9. Lowest layer of shale immediate roof exposed at mine roof horizon, showing angular quartz grains (bright white) scattered in a matrix of very fine-grained lathes of muscovite (rectangular, brightly colored yellow/pink/blue). Brown represents patchy iron staining. Field of view 2.4 mm at 40X, taken under crossed polars.

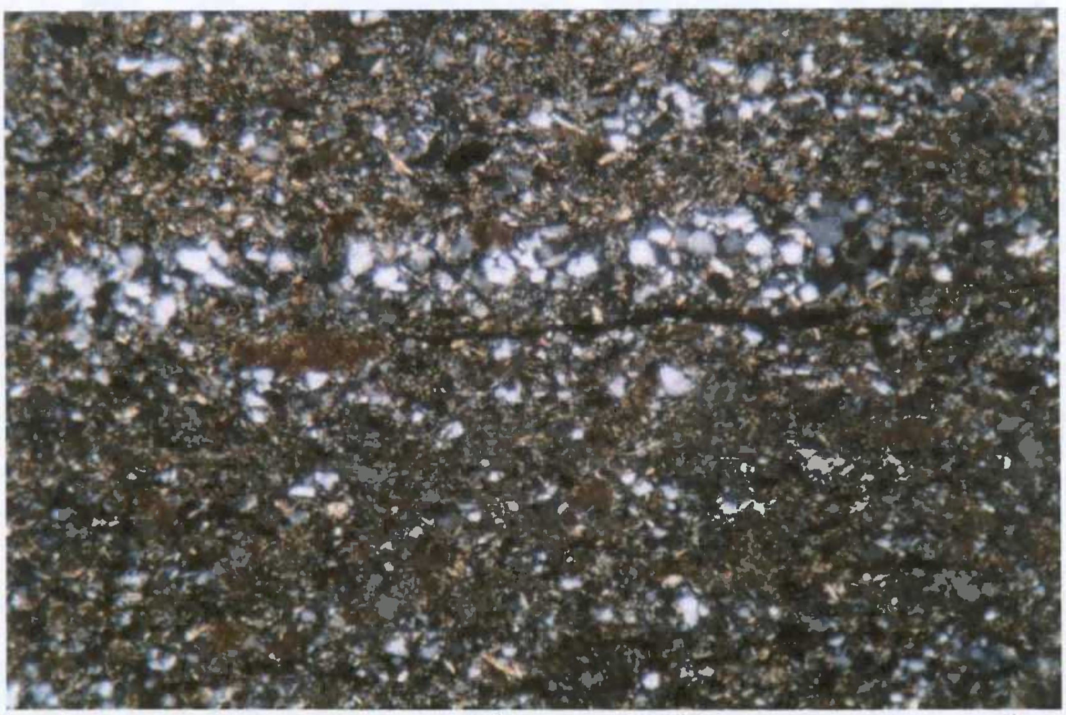

Figure 10. Lamination of angular quartz grains of "very fine sand" size. Angular grains touch along tangential contacts. Long axes of quartz grains and rectangular muscovite lathes are not strongly oriented parallel to bedding, indicating that burial compaction was not intense enough to force grain rotation. Field of view 2.4 mm at 40X, taken under crossed polars.

Sample 3045477-2 (Figures 11 and 12)

This sample is characterized by a matrix of fine-grained, randomly oriented muscovite lathes that are arranged in diffuse bedding laminations. Two beds are dominated by angular quartz grains that are sporadically distributed within a very fine sand-sized band. In the muscovite-dominated portion of the rock, angular quartz grains are sporadically distributed, with individual grains isolated by the muscovite-dominated matrix. In the quartz-dominated bed, angular quartz grains touch along tangential boundaries, and are intermixed with coarser-grained, randomly oriented, thin muscovite lathes. The finest-grained portions of the muscovite-dominated matrix host bedding-parallel delamination zones that are planes of preferential weakness. Discontinuous stringers of iron hydroxide, which may represent alteration of original biotite, are aligned parallel along diffuse bedding laminations. Despite the abundance of the discontinuous, bedding-parallel iron hydroxide stringers, a powerful magnet is not attracted to the sample.

The sample contains approximately 19% quartz, which ranges in size from 0.01 mm ("fine silt") to 0.1 mm ("very fine sand"). The remaining approximately 81% of the rock volume is dominated by muscovite, which ranges in size from 0.005 mm ("fine silt") to 0.04 mm ("medium silt"). Based on the size of grains, thickness and nature of bedding layers, and the content of clay-sized material, the shale sample is classified as muscovite-rich laminated siltstone.

In coarser-grained interbeds, the long axes of quartz grains are not strongly aligned with bedding laminations, forming obtuse angles, which indicates a low degree of compaction. In the fine-grained matrix, muscovite lathes are randomly oriented.

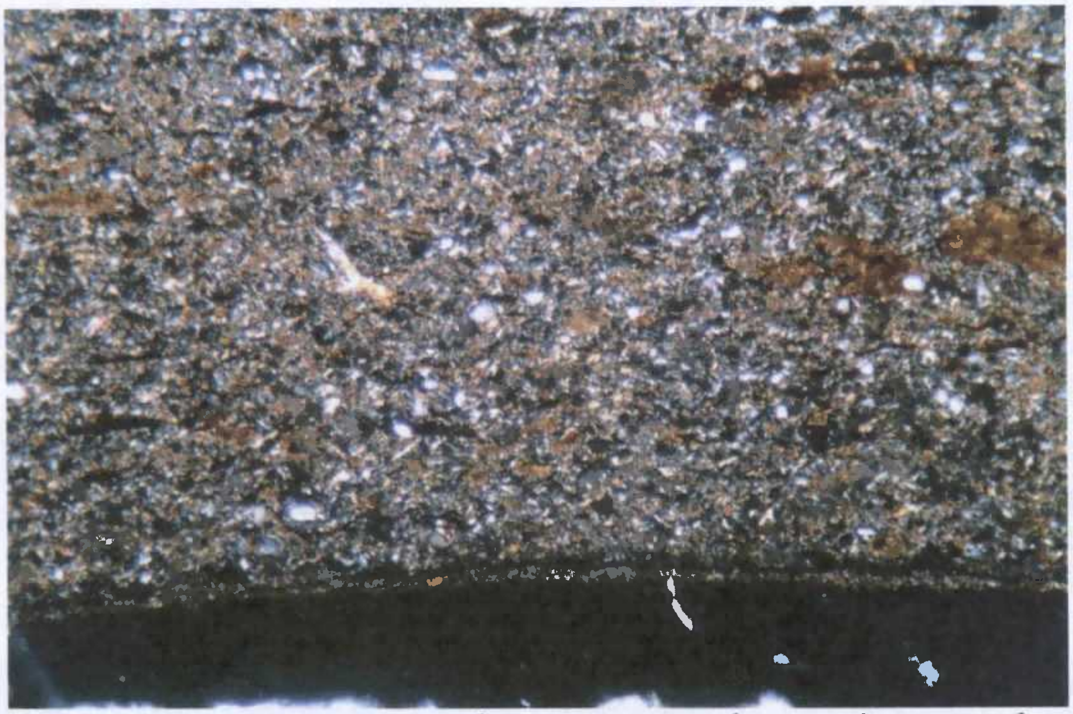

Figure 11. Lowest layer of shale immediate roof exposed at mine roof horizon, showing angular quartz grains (bright white) scattered throughout a matrix of very fine-grained muscovite (brightly colored pink/yellow). The muscovite-dominated matrix hosts patchy iron staining (brown) that is oriented along bedding laminations, and may represent leached original biotite flakes. Field of view2.4 mm at 40X, taken under crossed polars.

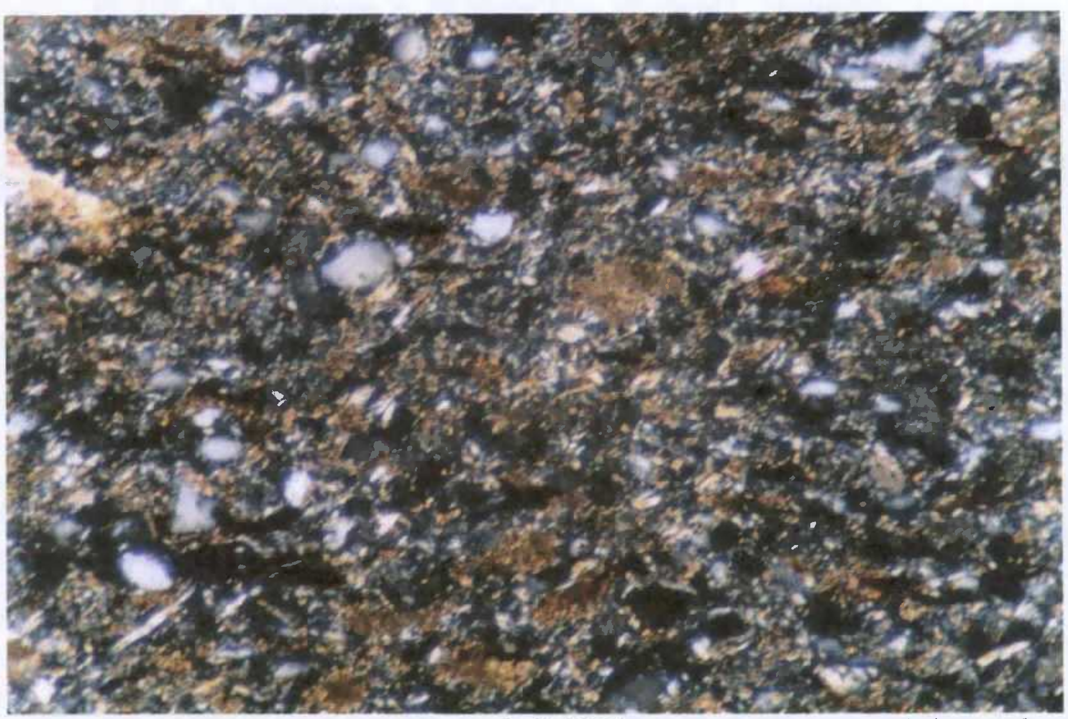

Figure 12. Same area as previous photo, showing individual, angular quartz grains (white and gray) isolated by surrounding, randomly oriented ragged flakes of muscovite (yellow/pink). Brown patchy areas represent iron staining. Field of view 1 mm at 100X, taken under crossed polars.

Sample 3045477-3 (Figures 13 and 14)

This sample is characterized by a matrix of fine-grained, randomly oriented muscovite lathes that are arranged in diffuse bedding laminations. Contacts between laminations are generally gradational, characterized by a changing grain size or mineral content. Several thin laminations are dominated by grains of angular quartz that are coarser-grained than those found in the muscovite-dominated portions of the rock. In the fine-grained, muscovite-dominated portion, angular quartz grains are sporadically scattered, with individual grains isolated by the surrounding muscovite matrix. In coarse-grained layers, quartz grains touch along angular, tangential boundaries or are more commonly slightly separated by a rim of very fine-grained muscovite. This sample exhibits more quartz-dominated laminations that are more sharply defined with respect to alternating muscovite layers, compared to the other samples. Thin, discontinuous stringers of iron hydroxide are abundantly distributed, aligned parallel to the bedding laminations that are defined by grains size and mineral content. The stringers may represent diagenetically altered biotite flakes. Despite the abundance of the stringers, a powerful magnet is not attracted to the sample. Very fine-grained laminations represent delamination horizons that are planes of preferential weakness.

The sample contains approximately 23% quartz, which ranges in size from 0.02 mm ("medium silt") to 0.2 mm ("fine sand"). The remaining 73% of the rock is dominated by muscovite, which ranges in size from 0.005 mm ("fine silt") to 0.2 mm ("fine sand").

The matrix of randomly oriented muscovite lathes, and the poorly aligned long axes of individual quartz grains in coarser-grained laminations indicates that the sample was not strongly compacted enough to force grain rotation.

Figure 13. Lowest layer of shale immediate roof exposed at mine roof horizon, showing gradational contact between very fine-grained, muscovite-dominated layer and overlying, coarser layer that hosts greater quartz content and larger grain sizes. Lower, very fine-grained layer localizes delamination zones (parallel black lines represent glass of microscope slide where rock separated).

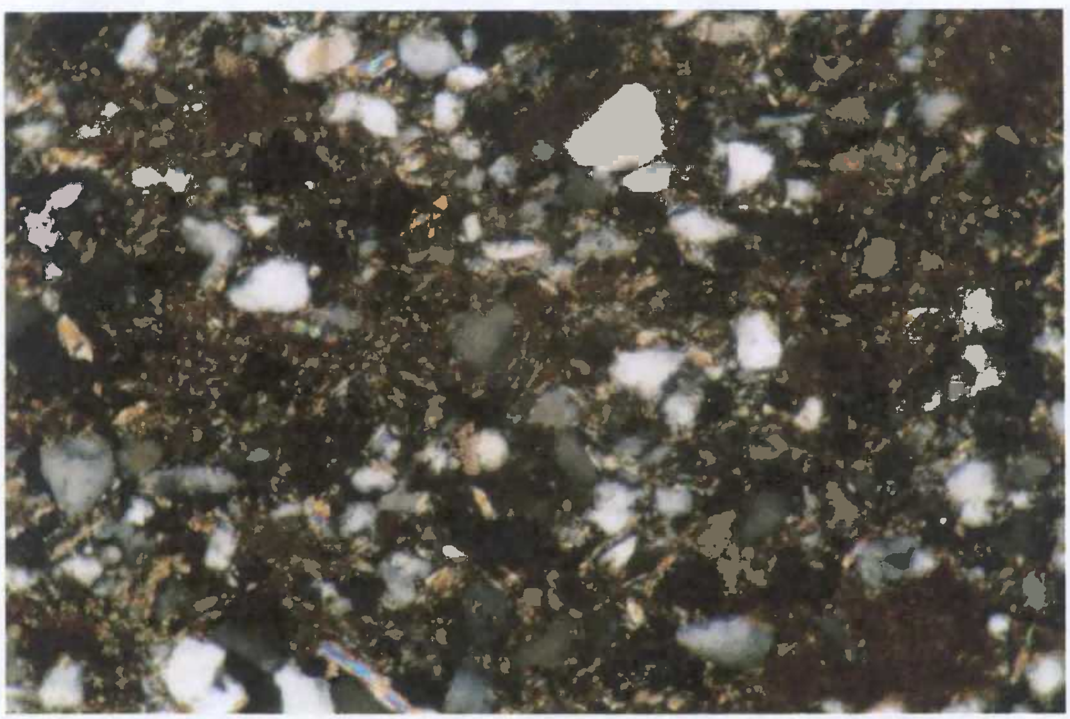

Figure 14. View of a coarser-grained, quartz-rich lamination, showing angular quartz grains (white and gray) isolated by the surrounding matrix of fine-grained muscovite lathes (pink/blue/yellow/green). Brown areas represent patchy iron staining. Field of view 1 mm at 100X, taken under crossed polars.

Sample 3045477-4 (Figures 15 and 16)

This sample is characterized by a matrix composed of very fine-grained, randomly oriented muscovite lathes that are arranged in diffuse bedding laminations. Contacts between laminations are generally diffuse, characterized by a gradational change in grain size and mineral content. In general, the very finest laminations host only muscovite, with increasing grain size associated with increasing quartz content, until some laminations are dominated by quartz. In fine-grained layers, angular quartz grains are sporadically distributed, with individual grains isolated by the surrounding matrix of fine-grained, randomly oriented muscovite. In coarser-grained layers, angular quartz grains dominate and touch along angular, tangential boundaries, or may be slightly separated by a rim of very fine-grained muscovite. The very finest layers host bedding-parallel delamination horizons that are planes of preferential weakness. Thin, discontinuous stringers of iron hydroxide are abundantly distributed, aligned parallel to bedding laminations. The stringers may represent diagenetically altered biotite flakes. Despite the presence of abundant stringers, a powerful magnet is not attracted to the sample. At the mine roof horizon, several of the thin stringers abruptly change their distance from each other along traverse, defining a compaction zone. This sample was collected from a portion of the R. J. Lee sample along which one of the pair of linear ridges ("anomalies") is located. A quartz-dominated lamination located 5 mm higher than the mine roof horizon also mirrors the iron hydroxide stringer-defined compaction zone. Although these textures suggest draping around an obdurate object, the matrix of randomly oriented muscovite lathes and layers of moderately aligned quartz grains indicate that the rock was not subjected to burial compaction significant enough to force grains to rotate into parallelism.

The sample hosts approximately 13% quartz, which ranges in size from 0.01 mm ("fine silt") to 0.09 mm ("very fine sand"). The remaining 87% of the rock volume is dominated by muscovite, which ranges in size from 0.005 mm ("fine silt") to 0.2 mm ("fine sand").

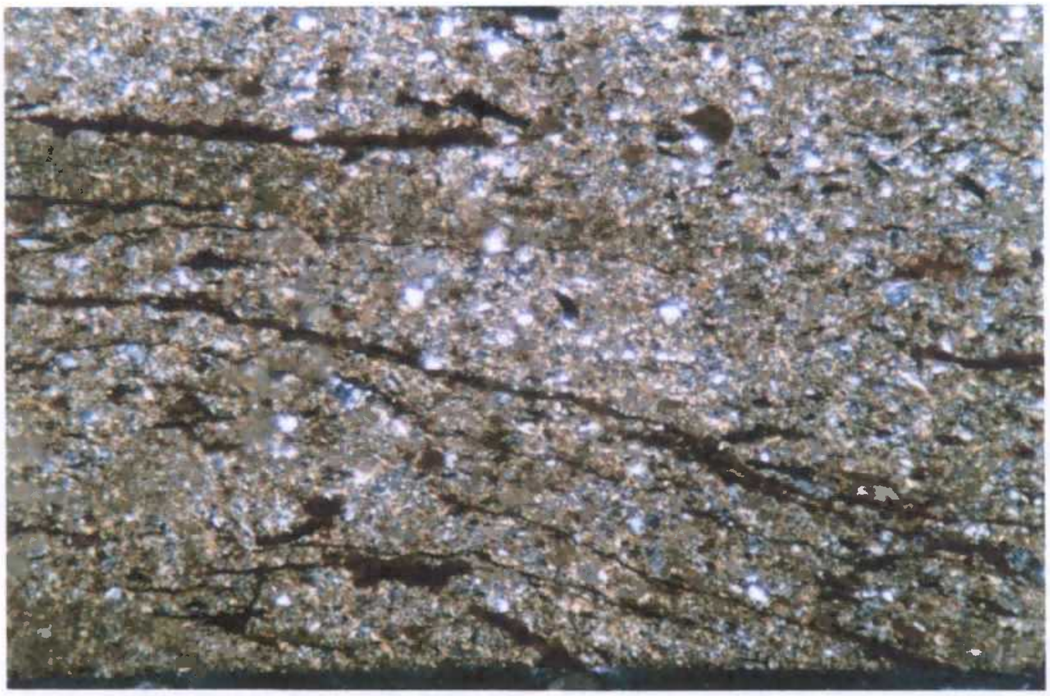

Figure 15. Long stringers of iron hydroxide (black, very dark brown) define bedding laminations in a compaction zone located near the margin of one of the linear ridges in Sample 3045477. Angular quartz grains (bright white) are scattered throughout the matrix of fine-grained muscovite (speckled pink/yellow with brown iron staining). Field of view 2.4 mm at 40X, taken under crossed polars.

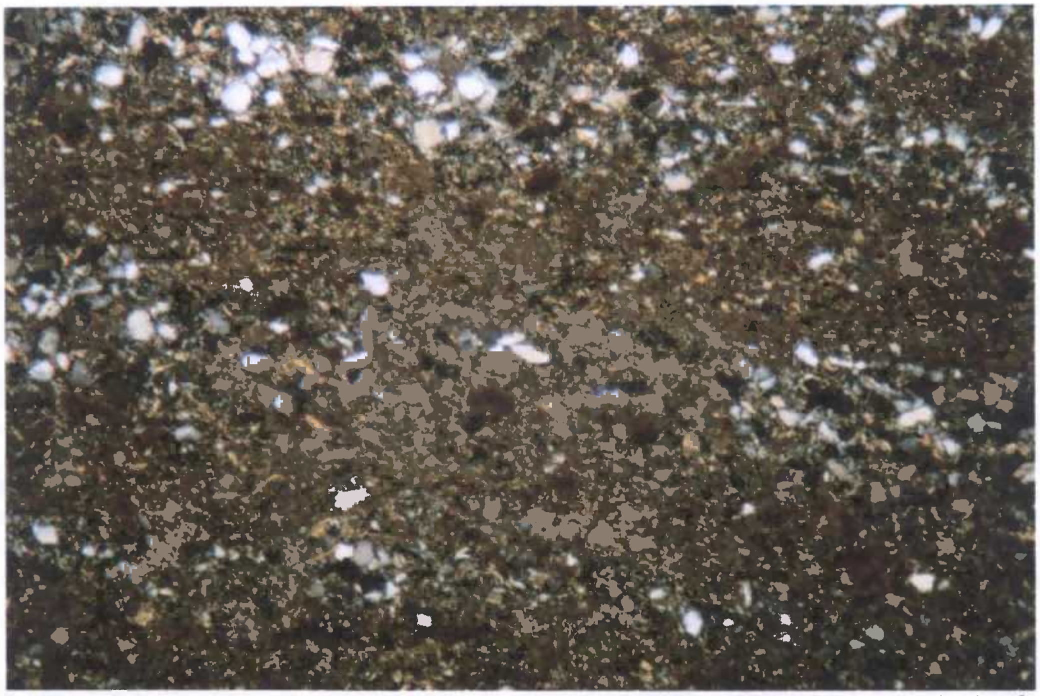

Figure 16. Field of view approximately 5 mm above the area in Figure 15, showing interbeds of quartz that gently rise from right to left above the compaction zone. Although locally a compaction zone, the long axes of quartz grains and muscovite lathes are not strongly oriented parallel to bedding, indicating that burial compaction was not sufficient to force grain rotation. Field of view 2.4 mm at 40X, taken under crossed polars.

Sample 3045477-5 (Figures 17 and 18)

This sample is characterized by a matrix of very fine-grained, randomly oriented muscovite lathes that are arranged in diffuse bedding laminations that exhibit gradational contacts based on changes in grain size and mineral content. The fine-grained laminations host scattered, fine-grained, angular quartz grains, with individual grains isolated by the surrounding muscovite matrix. Coarser-grained layers are dominated by angular quartz grains that touch along angular, tangential boundaries that are parallel to bedding contacts. Abundant, thin stringers of iron hydroxide are aligned parallel to bedding laminations and my represent diagenetic alteration of original biotite flakes. Despite the presence of abundant iron hydroxide, a powerful magnet is not attracted to the sample. In this sample, bedding contacts are particularly continuous and parallel. The finest-grained layers host delamination horizons that are planes of preferential weakness. Although bedding layers maintain constant thickness, the randomly oriented muscovite lathes and moderately aligned long axes of quartz grains indicate that the rock was not subjected to significant burial compaction.

The sample contains approximately 16% quartz, which ranges in size from 0.01 mm ("fine silt") to 0.2 mm ("very fine sand"). The remaining approximately 84% of the rock volume is dominated by muscovite, which ranges in size from 0.005 mm ("fine silt") to 0.2 mm ("fine sand").

Figure 17. Lowest level of shale immediate roof exposed at mine roof horizon, showing angular quartz grains (white) scattered and isolated in the very fine-grained, muscovite-dominated matrix. Field of view 2.4 mm at 40X, taken under crossed polars.

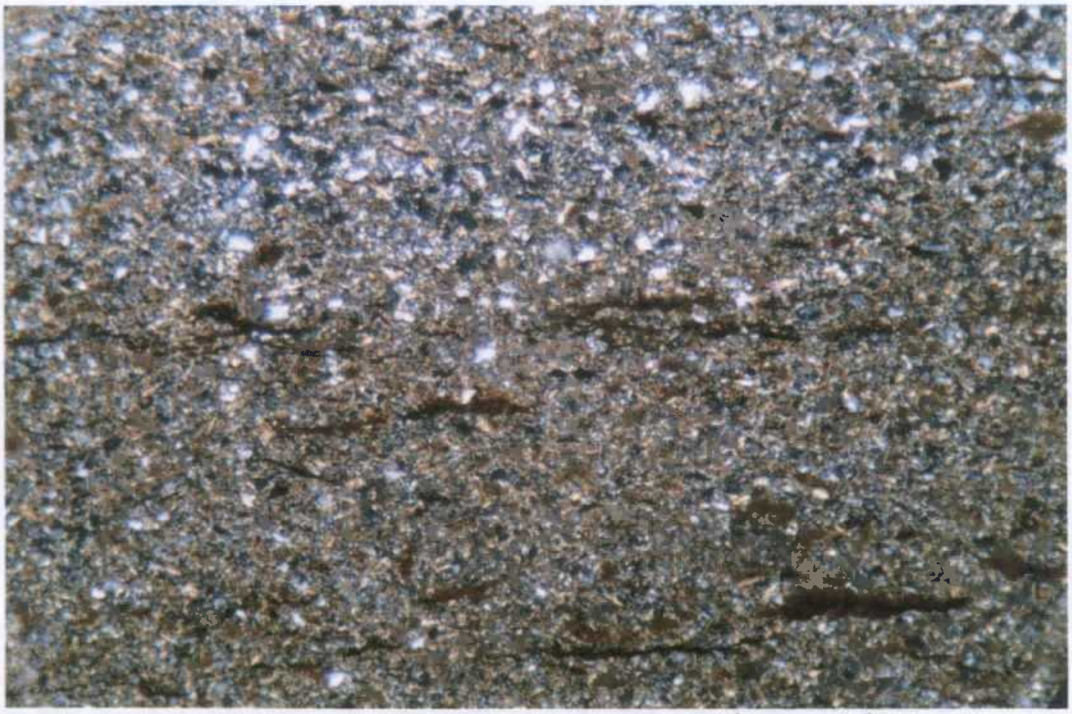

Figure 18. Very regular, continuous bedding contact between lower, fine-grained lamination characterized by scattered, angular quartz grains (bright white) in a very fine-grained matrix of muscovite (speckled yellow/pink), grading upward into lamination with abundant, angular quartz grains. Some quartz grains touch along tangential contacts, while most are isolated by surrounding muscovite. Discontinuous stringers of iron hydroxide (black to very dark brown), which may represent diagenetic alteration of original biotite flakes, are aligned parallel to define bedding. Field of view 2.4 mm at 40X, taken under crossed polars.

Sample 3045475 (Figures 19 and 20)

This sample is characterized by a matrix composed of very fine-grained, randomly oriented muscovite lathes that are arranged in diffuse bedding laminations that are gradational, based on changes in grain size and mineral content. Finer-grained layers host scattered grains of angular quartz, which are isolated by the surrounding, muscovite-dominated matrix. Coarser-grained layers are dominated by angular quartz grains, which touch along angular, tangential contacts. Thin stringers of iron hydroxide are abundantly distributed and aligned parallel to bedding laminations. The stringers have a crystal habit similar to mica suggesting that they represent diagenetic alteration of original biotite. Other stringers are very continuous and follow bedding laminations and pre-existing micro fractures, representing precipitation of iron along open-aperture planes. Despite the presence of abundant iron hydroxide, a powerful magnet is not attracted to the sample.

The sample contains approximately 17% quartz, which ranges in size from 0.01 mm ("fine silt") to 0.1 mm ("very fine sand"). The remaining approximately 83% of the rock's volume is dominated by muscovite, which ranges in size from 0.003 mm ("clay") to 0.1 mm ("very fine sand").

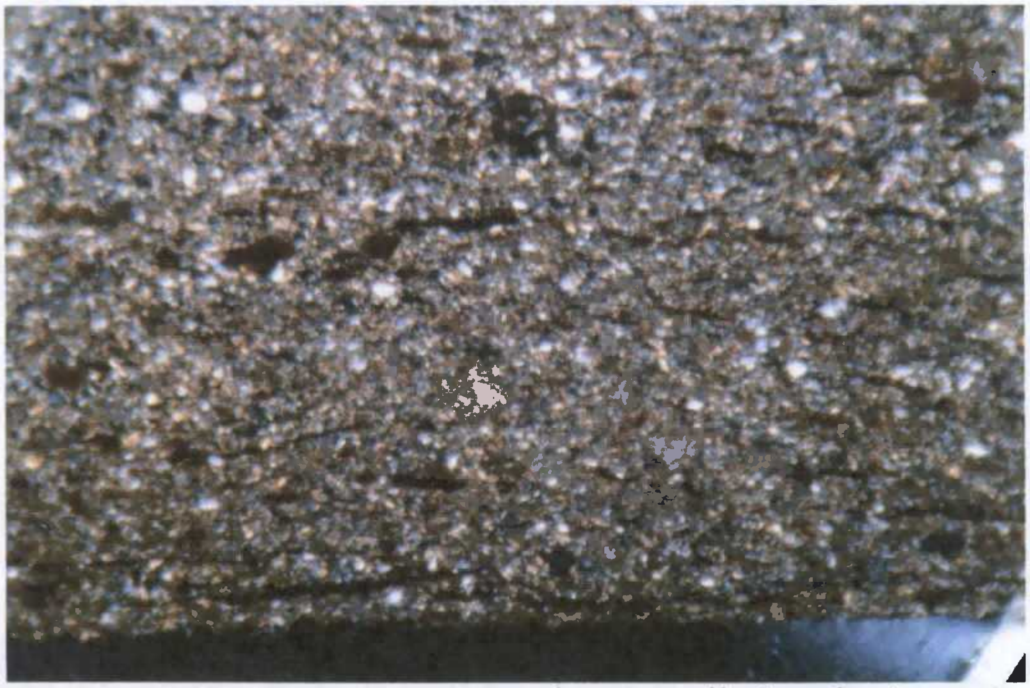

Figure 19. Lowest level of shale immediate roof exposed at mine roof horizon, showing angular quartz grains (bright white) scattered throughout a matrix composed of fine-grained muscovite lathes (speckled yellow/blue/pink/green). Wispy stringers of iron hydroxide (black to very dark brown) are aligned along bedding laminations, and may represent diagenetic alteration of original biotite flakes. Field of view 2.4 mm at 40X, taken under crossed polars.

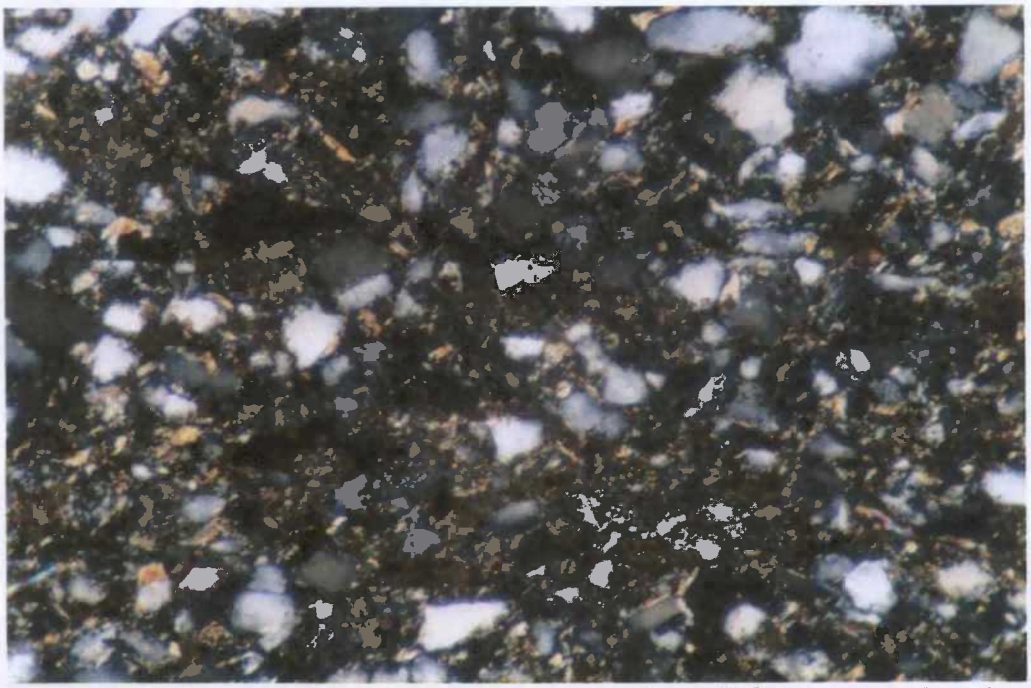

Figure 20. Angular quartz grains (white and gray) touch along tangential contacts nearly isolated in a matrix of randomly oriented muscovite lathes (yellow). Field of view 1 mm at 100X, taken under crossed polars.