Stratigraphy of the Proterozoic Revett Formation, Coeur d'Alene District, Idaho

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60. Stratigraphy of part of the lower St Regis and upper Revett Formations, as exposed in Reindeer Queen DDH #85-1. Depth, as measured along the core, has been converted trigonometrically to stratigraphic thickness.

Abstract

The Proterozoic Revett Formation of the Belt Supergroup contains three informal members that can be identified throughout the Coeur d'Alene mining district of northern Idaho. The lower Revett Formation is dominated by quartzite, but also contains intervals of siltite. The middle Revett consists predominantly of siltite, though quartzite and argillite locally form significant intervals. The upper Revett consists of intervals of quartzite that alternate with intervals of siltite and/or thin-bedded argillite.

These units show dramatic changes in thickness and sedimentary facies within the Coeur d'Alene mining district; changes that are more abrupt and extreme than seen elsewhere in the Belt basin. The regionally significant Osburn fault bisects the district, with 20 to 30 km of post-mineralization right-lateral strike-slip offset. South of this fault, the upper Revett is 640 m thick at the Bunker Hill mine in the west, 450 to 500 m thick in the centrally located Silver Belt, and over 550 m thick at the Reindeer Queen deposit to the east. North of the Osburn fault, the upper Revett is approximately 120 m thick in the vicinity of the Lucky Friday mine, but abruptly thins to 45 to 90 m to the north and northeast, in the southern end of the western Montana copper sulfide belt.

The middle Revett Formation south of the Osburn fault appears to be 400 to 450 m thick. North of the Osburn Fault, the middle Revett thins to approximately 120 m in the Lucky Friday area, and to approximately 60 m at Military Gulch. The lower Revett Formation is approximately 1650 m thick south of the Osburn fault, but thins to 400 to 450 m thick to the north of the Osburn fault. Observed thickness changes support previous hypotheses that the current Osburn fault coincides with a Proterozoic synsedimentary fault that controlled sedimentation in this region.

Introduction

> *"The harmonizing of the nomenclature of the Belt group, though desirable, is an object whose attainment must be deferred without impatience for some years to come"*
>
> (Calkins, in Ransome and Calkins, 1908, p. 26)

In 1984, Garth Crosby of Hecla Mining Company founded the Revett study group, which consisted of a board representing five companies in the Coeur d'Alene mining district: Bunker Limited Partnership, Callahan Mining Company, Coeur d'Alene Mines, Hecla Mining Company, and Sunshine Mining Company. The purpose of the Revett study group was to conduct a private study of the stratigraphy of the Revett and lower St. Regis Formations in the Coeur d'Alene Mining district. I was hired to conduct this study, and from May 1984 through April 1985 acquired data, and produced stratigraphic sections showing the character of the Revett Formation in various locations throughout the district. The final report for the project was limited to 12 copies that were released to the mining companies (Mauk, 1985), and with the exception of one abstract (Mauk, 2000), the results have not been published or publicly available.

This investigation documented the stratigraphy of the Revett Formation throughout the district, and also showed that there are remarkable sedimentary facies and thickness changes that occur within the district. This Open-File Report was prepared in order to archive the data so that knowledge of the stratigraphy in this important metal mining district would not be lost, and would be publicly available. The written portion of this Open-File Report is modified from its original version, but most of the plates are scanned images of the original plates from my 1985 report.

Regional Geology

Metasedimentary rocks of the Middle Proterozoic Belt Supergroup crop out over much of eastern Washington, northern Idaho, and northwestern Montana (Figure 1). The Belt Supergroup contains four major stratigraphic divisions: the lower Belt, the Ravalli Group, the middle Belt carbonate interval, and the Missoula Group (Harrison, 1972; Figure 2). The Burke, Revett and St Regis Formations form the Ravalli Group, and indeed their type areas are in or near the Coeur d'Alene mining district. The Revett Formation is economically important because it hosts most of the ore in the Coeur d'Alene mining district, and all of the ore-grade stratabound copper-silver deposits of the western Montana copper sulfide belt (Fryklund, 1964; Hobbs and others, 1965; Harrison, 1972, 1974;).

The Revett Formation was deposited between 1468 and 1454 Ma, as bracketed by the age of the underlying lower Belt and the overlying middle Belt carbonate. In southern Canada, the Moyie sills intrude the Aldridge Formation, which is the lateral equivalent of the Prichard Formation of the lower Belt. Zircons from the Moyie sills provide U-Pb ages of 1468 ± 2 Ma, which is approximately the age of the Aldridge Formation, because textural evidence indicates that the sills intruded while the sediments were still soft (Anderson and Davis, 1995). SHRIMP U-Pb zircon analyses of a tuff in the upper part of the Helena Formation, which is the middle Belt carbonate unit in the eastern part of the Belt Supergroup, yielded an age of 1454 ± 9 Ma (Evans and others, 2000).

Local Geology

The Coeur d'Alene mining district is the second largest producer of silver in the world, having produced over 34,000 tonnes of silver, 7.2 million tonnes of lead and 2.8 million tonnes of zinc (Long, 1998). Mines in the district exploit narrow, relatively high-grade veins that most workers agree formed from reduced fluids under mesothermal conditions (Leach and others, 1988). The timing of formation of the veins is controversial, with some workers advocating both Proterozoic and Late Cretaceous to early Tertiary stages of mineralization (Leach and others, 1988, 1998). Other workers maintain that all mineralization formed in the Late Cretaceous to early Tertiary (e.g. Eaton and others, 1995; Criss and Eaton, 1998; White, 1998).

The structural geology of the district is complex, with up to five distinct structural episodes (White, 1998). The district lies within the regionally significant Lewis and Clark line,

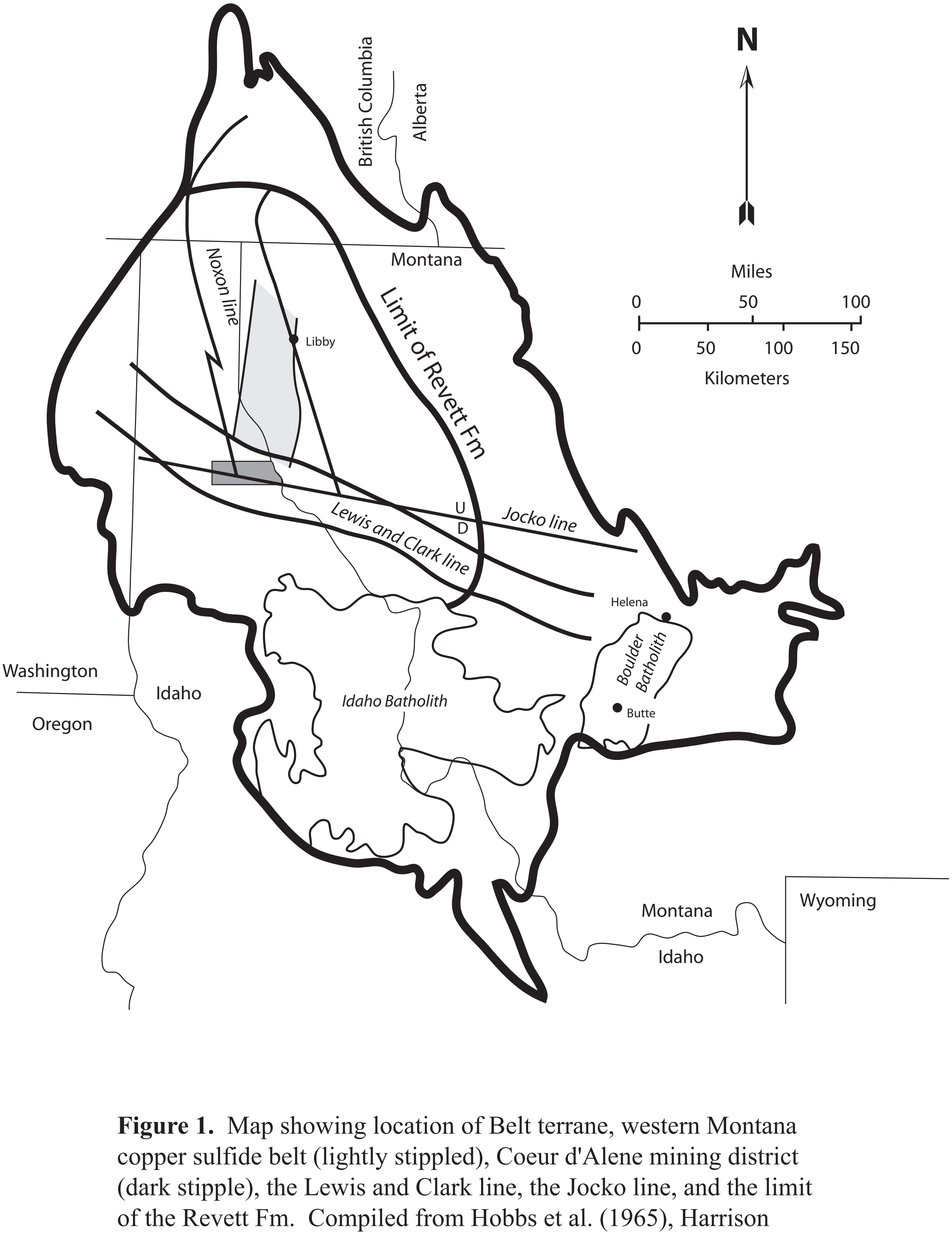

Figure 1. Map showing location of Belt terrane, western Montana copper sulfide belt (lightly stippled), Coeur d'Alene mining district (dark stipple), the Lewis and Clark line, the Jocko line, and the limit of the Revett Fm. Compiled from Hobbs et al. (1965), Harrison (1972, 1974), Harrison et al. (1974), and Winston (1986, 2000).

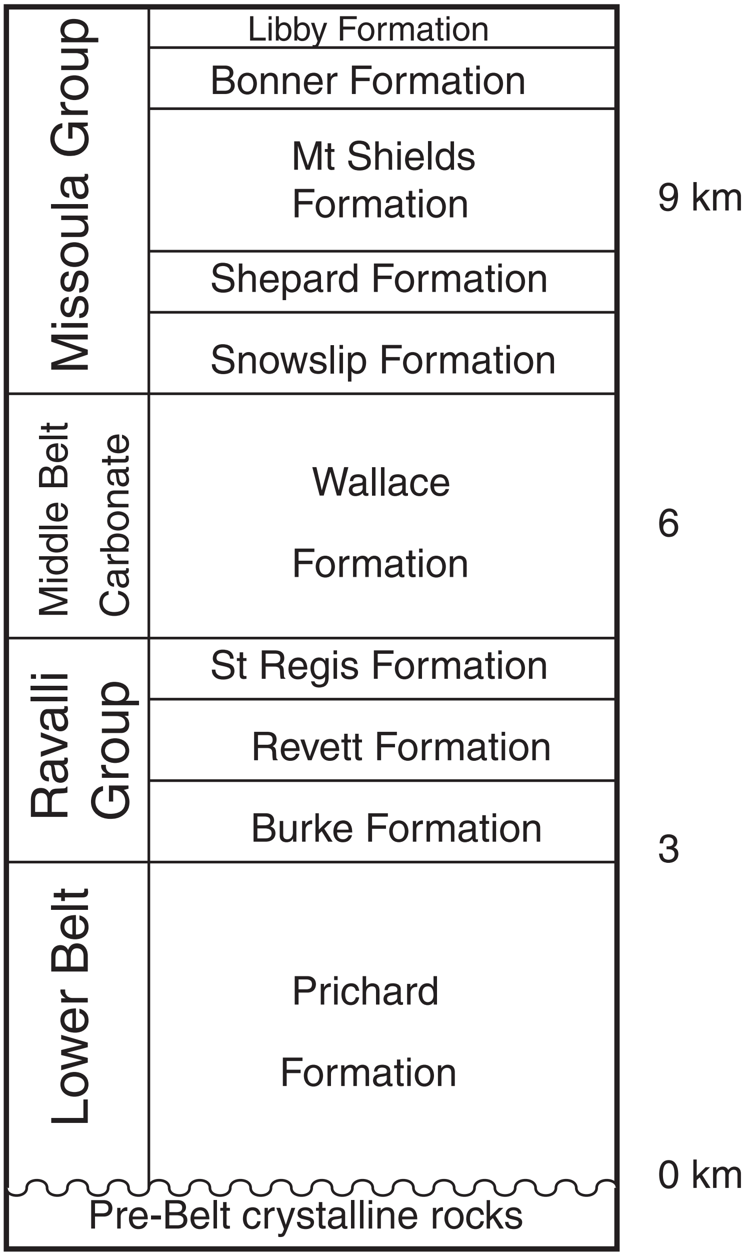

Figure 2. Stratigraphic subdivisions of the Belt Supergroup in the central and western portion of the Belt terrane.

and is bisected by the Osburn fault, which shows 20 to 30 km of right lateral strike slip displacement (Hobbs and others, 1965; Bennett and Venkatakrishnan, 1982).

Methods

I described all sections using the core logging system of Gordon J. Hughes, Jr., as modified and described in Appendix A, at a scale of 1:120 (1 inch = 10 feet). Outcrop and underground sections were measured using a Jacob's Staff. Drill core was also logged at a scale of 1:120, and distances along drill core axes were converted to stratigraphic thickness using standard trigonometric methods (e.g. Billings, 1942). In total, I described over 13 kilometers (over 43,000 feet) of section and drill core. This report also includes unpublished data from Brian White from the Bunker Hill, Crescent and Lucky Friday mines (Appendix B). Figure 3 shows the location of sections measured in this study.

Sections were compiled to various scales, principally 1" = 100' and 1" = 500', and this report contains the 1" = 100' compilations as Plates. Appendix C contains section location maps.

After October 1984, carbonate type and content was estimated using the staining method of Dickson (1966), which uses 0.2 g of alizarin red S per 100 cc of 1.5% HCl solution and 2.0 g of potassium ferrocyanide per 100 cc of 1.5% HCl solution. These are mixed in a ratio of three parts alizarin red S solution to two parts potassium ferrocyanide solution. This solution stains ankerite blue and calcite purple. Calcite fizzes weakly in the 1.5% HCl solution because it is more reactive than ankerite or siderite. Siderite will not react with the stain, but can be recognized readily in hand sample by its distinctive yellow-tan-brown color.

Rock Types in the Revett Formation

As emphasized by Winston (1986, 2000), describing rock types in the Belt Supergroup can be problematic. Features that are easy to document, such as color, may be altered by diagenetic processes. In the Coeur d'Alene district, both color and hardness can change due to alteration, where rocks that were originally gray to lavender can be bleached to light green to light gray. Similarly, relatively soft rocks may be silicified near some veins and structures, making them uncharacteristically hard. Therefore, in the Coeur d'Alene district, bed thickness and sedimentary structures are the most reliable indicators of rock type.

The Revett Formation contains six rock types in the Coeur d'Alene district, with different rock types identified based on grain size, degree of sorting, sedimentary structures and hardness: vitreous quartzite, subvitreous quartzite, sericitic quartzite, blocky siltite, argillitic siltite and thin-bedded argillite. These rocks represent a continuum of hardness, grain size, sorting and bed thickness (Table 1).

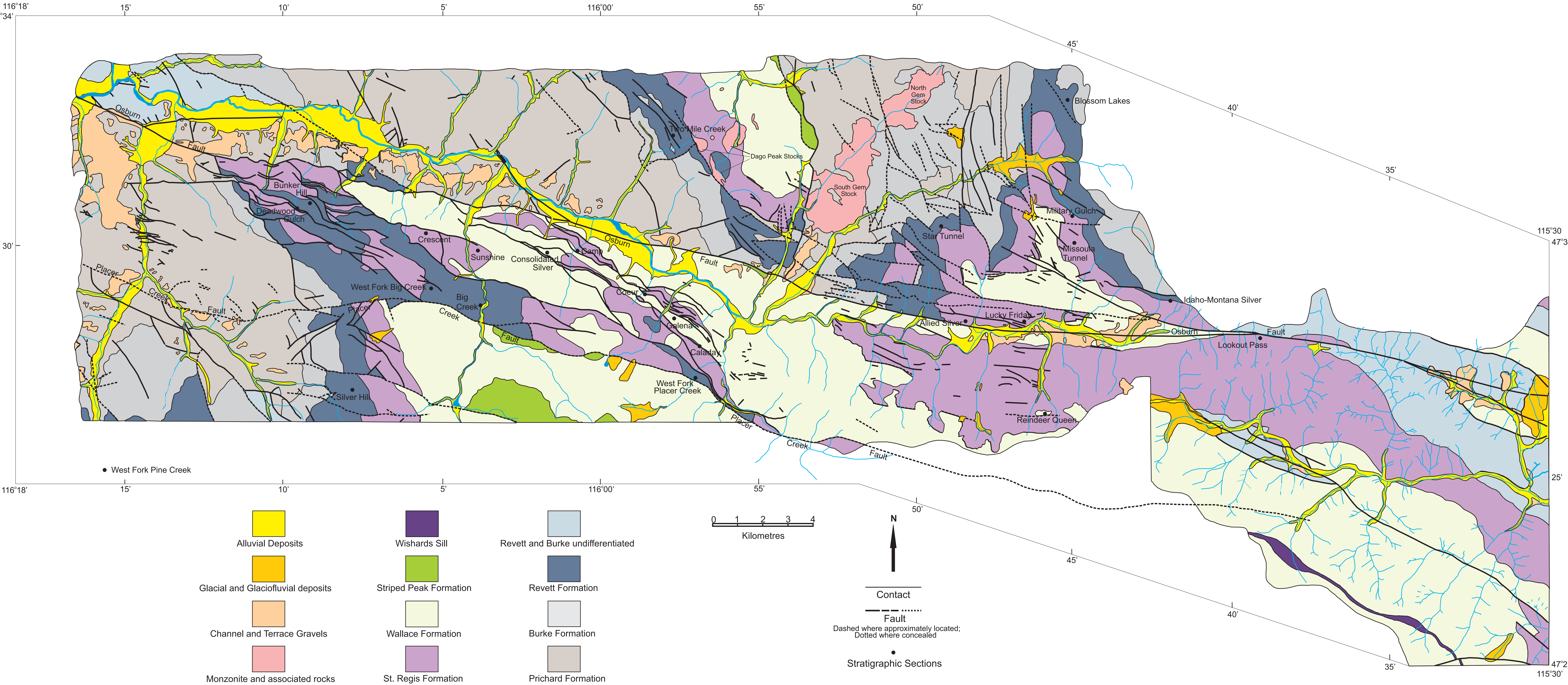

Figure 3. Generalized geologic map of the Coeur d'Alene district, showing the location of sections measured during this study.

Table 1. Properties of the rock types of the Revett and lower St Regis Formations.

Rock Type	Color	Hardness	Grain Size	Sorting	Bed Thickness	Sedimentary Structures
Vitreous quartzite	white light gray	very hard	medium sand fine sand	very well well	0.3 to 2 m Ave = 0.6-1 m	cross-strata, flat laminations
Subvitreous quartzite	light gray light green tan	very hard	medium sand fine sand very fine sand	well	0.3 to 2 m Ave = 0.6-1 m	cross-strata, flat laminations, ripple cross-laminae, hummocky cross-stratification?
Sericitic quartzite	light green tan lavender	hard moderately hard	fine sand very fine sand	well moderately	0.3 to 1.7 m Ave = 0.5-1 m	flat laminations, ripple cross-laminae
Blocky siltite	green light green tan lavender	moderately hard soft	silt very fine sand	moderately	5 to 25 cm Ave = 18 cm	ripple cross-laminae, flat laminations, massive
Argillitic siltite	green light green tan lavender	soft	silt very fine sand clay	moderately poorly	0.75 to 5 cm	lenticular bedding, wavy bedding, parallel bedding, synaeresis cracks, mud skins, mud chips, graded beds, flaser bedding
Thin-bedded argillite	lavender	soft	silt very fine sand clay	moderately poorly	0.75 to 10 cm	sedimentary couplets, wavy bedding, lenticular bedding, parallel bedding, graded bedding, synaeresis cracks, desiccation cracks, mud chips

Vitreous quartzite

Vitreous quartzite is perhaps the most distinctive rock type of the Revett Formation, forming a substantial portion of the exposures in the cirque wall at Revett Lake, where Calkins (in Ransome, 1905) named the unit. This rock type consists of very well- to well-sorted, medium- to fine-grained sandstone, which is now metamorphosed to quartzite. It forms white to light gray, very hard beds 0.3 to 2 m thick (Figure 4). In some places, vitreous quartzite is nearly snow-white. Most beds are 0.6 to 1 m thick, and are commonly cross-stratified, flat laminated or massive. Most cross-strata occur as tabular sets of planar cross-strata with angular to tangential bases, though lenticular sets of trough cross-strata occur in a few places.

Figure 4. Vitreous quartzite at the top of the Lower Revett at Big Creek.

Graphic logs show vitreous quartzite as medium sand with 3-5% sericite and/or muscovite.

Subvitreous quartzite

Subvitreous quartzite is transitional between vitreous quartzite and sericitic quartzite. Subvitreous quartzite consists of well- to moderately-sorted medium- to very fine-grained sandstone that has been metamorphosed to quartzite. It forms light green to light gray to tan, very hard beds that are 0.3 to 2 m thick (Figure 5). Most beds are 0.6 to 1 m thick, and may be cross-stratified, flat laminated, or ripple cross laminated. In a few places, subvitreous quartzite may contain hummocky cross-stratification.

Figure 5. Photograph of subvitreous to sericitic quartzite beds to 1 m thick. Jacob's staff is 1.5 m long.

Graphic logs portray subvitreous quartzite as fine sand with 3-7% sericite and/or phengite.

Sericitic quartzite

Sericitic quartzite consists of moderately- to well-sorted, fine- to very fine-grained sandstone that has been metamorphosed to quartzite. It forms lavender to tan, hard to moderately hard beds 0.3 to 1.7 m thick (Figure 6). Most beds are 0.5 to 1 m thick, and are commonly flat-laminated or ripple cross-laminated. Oscillation ripples locally cap sericitic quartzite beds. Some beds contain scoured bases, but in most places, the bases of beds appear to be non-erosional.

Figure 6. Photograph of sericitic quartzite showing scour and flat laminations. Unit is underlain by argillitic siltite.

Graphic logs show sericitic quartzite as fine sand with 5-15% sericite and/or phengite. Where sericitic quartzite appears to be very impure, I represented it as fine sand with 10-20% sericite and/or phengite.

Blocky siltite

Blocky siltite grades into coarser-grained sericitic quartzite and finer-grained argillitic siltite, and in some cases it can be difficult to distinguish from these other rock types. Generally, blocky siltite consists of moderately-sorted, impure very fine-grained sandstone or siltstone that has been metamorphosed to siltite. It forms moderately hard to soft, green, light green, tan or lavender beds 5 to 25 cm thick (Figure 7). Most beds are approximately 15 cm thick, and are commonly ripple cross-laminated, flat-laminated, or massive. I have not observed desiccation cracks in this rock type, and graded beds rarely occur. Bed thickness is the most effective way to distinguish blocky siltite from argillitic siltite or sericitic quartzite. Argillitic siltite contains distinct layers less than 2.5 cm thick, whereas sericitic quartzite forms beds that are over 30 cm thick. The layering in blocky siltite can be indistinct, particularly in drill core, which can make it difficult to distinguish from sericitic quartzite. However, in underground and surface exposures, bed thickness is usually discernable.

Figure 7. Photograph of medium-bedded blocky siltite.

Graphic logs portray blocky siltite as medium bedded silt with 10-25% sericite and/or phengite.

Argillitic siltite

This rock contains moderately- to poorly-sorted silt, very fine-grained sand and clay that have been metamorphosed to form siltite. It forms green, light green, tan or lavender soft beds and laminae 0.7 to 5 cm thick. In some places, argillitic siltite forms distinct layers that are nearly siltite-argillite couplets (Figure 8), indicating that this rock type is transitional with thin-bedded argillite. Lenticular bedding, wavy bedding, and parallel bedding commonly occur in this rock type; synaeresis cracks, mud skins, mud chips, and graded beds occur locally. Desiccation cracks and flaser bedding (ripple laminations) rarely occur in this rock type.

Figure 8. Photograph of blocky siltite that grades up to argillitic siltite. Note the well-formed wavy bedding.

Graphic logs show argillitic siltite as thin-bedded or laminated silt with interstratified clayey pelite that contains 15-30% sericite and/or phengite.

Thin-bedded argillite

Although it occurs locally in the Burke and Revett Formations, thin-bedded argillite is most typical of the St Regis Formation. This rock type consists of moderately- to poorly-sorted, very fine-grained sand to silt to clay that has been metamorphosed to argillite. This rock type is characterized by distinct sedimentary couplets 0.7 to 10 cm thick (Figure 9). A layer of sand or silt forms the basal two-thirds to three-quarters of each couplet; clay forms the upper portion. The coupleted nature of this rock type distinguishes it from argillitic siltite. In the Coeur d'Alene district, this rock is purple nearly everywhere, though it may be green in areas of hydrothermal bleaching. Characteristically, this rock type contains abundant sedimentary structures, including wavy bedding, lenticular bedding, parallel bedding, graded bedding, synaeresis cracks, desiccation cracks, mud skins and mud chips. Flaser bedding and fluid escape structures rarely occur in this rock type.

Figure 9. Photograph of thin-bedded argillite. Mud layers are lavender; sand layers are white. A large fluid escape structure occurs in the center of the photograph. Lenticular bedding, flaser bedding, and desiccation cracks are also present.

Graphic logs show thin-bedded argillite and thin-bedded sandy pelite with interstratified clayey pelite that contains 20-30% sericite and/or phengite.

Stratigraphy of the Revett Formation

General background, previous work

Most of the work in the Coeur d'Alene district that related to stratigraphy was focussed on map-scale problems, such as how to define mappable units in the Belt Supergroup. The first detailed stratigraphic study of the Revett Formation in the Coeur d'Alene district was in the vicinity of the Bunker Hill mine near Kellogg (White and others, 1977; White and Winston, 1982). These workers identified informal lower, middle and upper members of the Revett Formation, based on exposures at Big Creek, as well as detailed work within the Bunker Hill mine and on the Bunker Hill property (Figure 10). The lower member consists of thick units of sericitic, subvitreous and vitreous quartzite that alternate with thinner units of siltite. The middle Revett is dominated by argillitic and/or blocky siltite, though quartzite and thin-bedded argillite are locally important constituents. The upper member contains sequences of quartzite that alternate with sequences of siltite and/or thin-bedded argillite.

At the time of this study, a number of theses had been completed that addressed the stratigraphy of the Revett Formation (Hrabar, 1971; Bowden, 1977; Wingerter, 1982; Alleman, 1983; Hayes, 1983; Mauk, 1983). Many of these included stratigraphic descriptions from one or more localities in the Coeur d'Alene district, but none of these studies included work in any of the mines.

This study was the first (and to date only) attempt to document the nature of the Revett Formation throughout the Coeur d'Alene mining district, using surface, underground and drill core exposures.

Contact criteria

Calkins (in Ransome, 1905) first used the term "Revett quartzite" for exposures surrounding Revett Lakes. Other workers used this terminology (e.g. Ransome and Calkins, 1908; Umpelby and Jones, 1923; Shenon and McConnel, 1939; and Hobbs and others, 1965) until Harrison and Campbell (1963) formally changed the name to the Revett Formation because the former name gave a "false sense of lithologic homogeneity" to a unit that in most places consists of no more than 50% quartzite. While mapping in the Clark Fork quadrangle, Harrison and Jobin (1963) placed the contact of the Revett so as "to include all thick layers of white to buff blocky very thinly crossbedded quartzite". This practice was followed, with minor modification, by Bowden (1977), Mauk (1983) and Hayes (1983). Other workers use the presence of siltite to argillite couplets and abundant mud chips (e.g. Alleman, 1983) to mark the base of the St. Regis Formation.

Recognition that the upper Revett consists of alternating packages of quartzite and siltite and/or thin-bedded argillite allowed an important paradigm shift in recognition of stratigraphic units in the Coeur d'Alene district. Early workers tended to see the Revett/St Regis contact as transitional from massive quartzite of the Revett Formation through siltite and argillite until

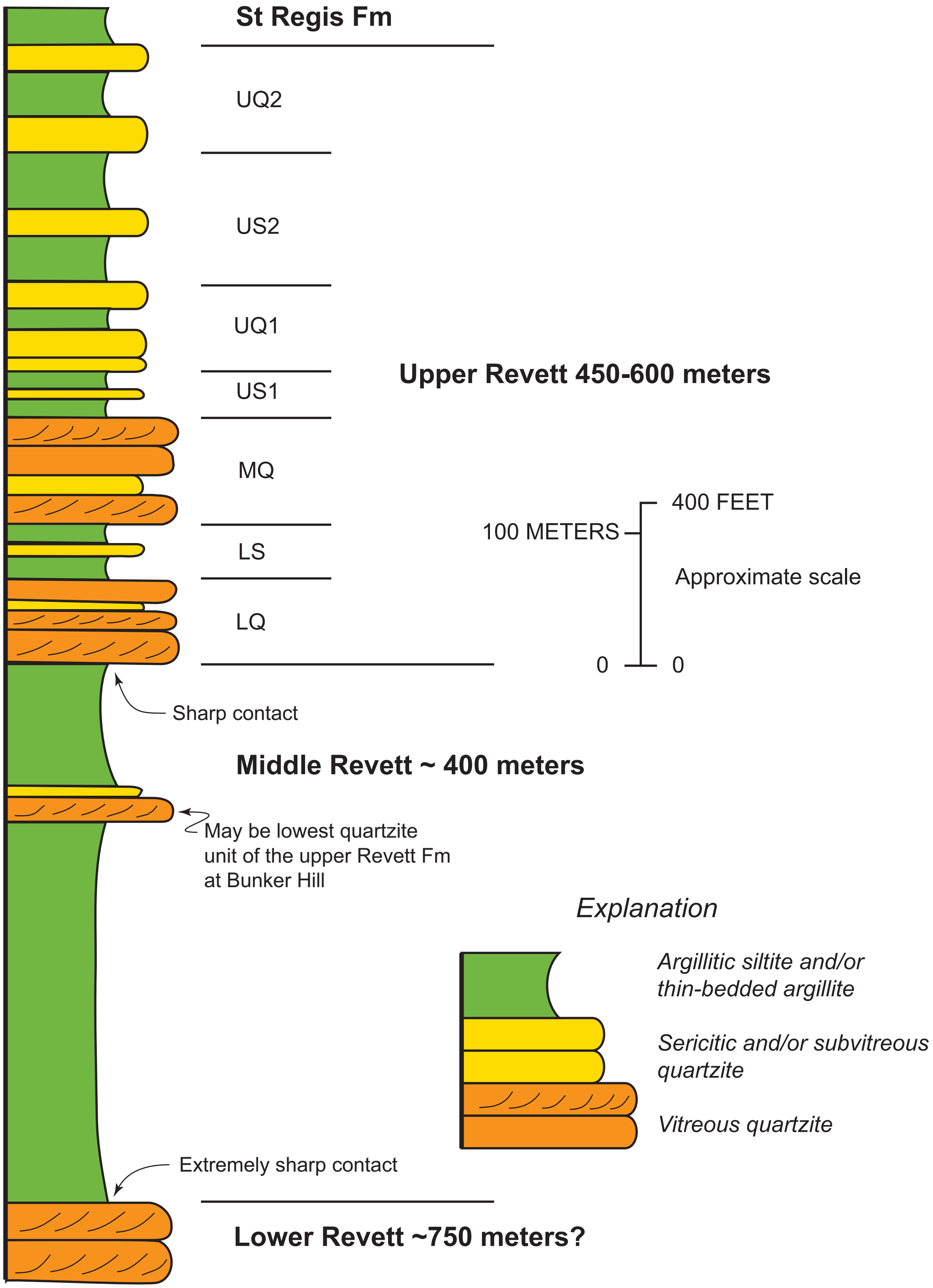

Figure 10. Generalized stratigraphic section of the Revett Fm south of the Osburn fault, showing stratigraphic subdivisions within the upper Revett.

typical St Regis lithologies of siltite and argillite were encountered. This transition zone was believed to have variable thickness throughout the district, but due to its transitional nature, it was difficult to quantify and never was it accurately measured. Indeed, different workers mapped the transition zone differently, depending on vagaries of exposure, personal preference, etc. However, recognition that the Revett Formation contains packets of quartzite that alternate with packets of finer-grained rocks allowed a more precise definition of the Revett/St Regis contact. White and Winston (1982) placed the contact between the Revett and St Regis Formations at the lowest purple argillite. During this study, I adopted Hayes' (1983) recommendation to place the top of the Revett Formation at the top of the highest coset of thick sets of quartzite. This usage is preferred for several reasons.

1. It bases the criterion for the upper contact of the Revett Formation on the presence of quartzite, thereby retaining some of the essence of Calkins' (in Ransome, 1905) original usage.
2. Mud chips and siltite to argillite couplets occur locally in all members of the Revett Formation. Within the Coeur d'Alene district, I have observed these sedimentary structures and bedforms in the middle and upper Revett, so they are not reliable criteria.
3. Hayes' (1983) definition provides a mappable and consistent contact that is independent of color. The Coeur d'Alene district has significant variations in the color of its strata due to both diagenetic and hydrothermal processes. Because of these affects, color boundaries cross-cut stratigraphy on both local and regional scales.
4. This definition relies on rock types rather than the presence/absence of cross-stratification, as proposed by Harrison and Jobin (1963). In many places, the uppermost thick-bedded quartzites of the Revett Formation are not cross-stratified. In other areas, identification of cross-stratification may be difficult due to poor exposure, etc.
5. The base of the St Regis commonly consists of thin- to medium-bedded, argillitic or blocky siltite with only minor thin-bedded argillite. The use of mud chips and sedimentary couplets to define the Revett/St Regis boundary would, in some places, dictate inclusion of part of this basal zone of St Regis into the Revett. In these regions, it is critical to distinguished blocky siltite from sericitic quartzite, or stratigraphic correlations will be greatly complicated.

The Revett/St Regis transition zone has not been defined in the literature. The term is generally applied to a stratigraphic interval that contains lithologies characteristic of the Revett and St Regis Formations, but the term has different connotations for different workers. For the purpose of this study, I define the Revett/St Regis transition zone as the stratigraphic interval that contains one or more sequences of thick-bedded quartzite as well as one or more sequences of thin-bedded argillite.

Unfortunately, Hayes' (1983) definition cannot be used to place the Burke/Revett boundary, because sequences of thick-bedded quartzite occur within the upper member of the Burke Formation (Mauk, 1983). Generally, this contact is placed where thinner-bedded, sericitic quartzite of the Burke Formation passes up to thicker-bedded, vitreous to subvitreous, more commonly cross-stratified quartzite of the Revett Formation.

Stratigraphic correlations: General remarks

One of the great difficulties in working in the Belt Supergroup is the virtual lack of marker beds within the sedimentary sequence, which makes stratigraphic correlations difficult and problematic. In this study, I established stratigraphic correlations using several criteria. I anticipated that thick sequences of quartzite would be relatively continuous, although they might change thickness or character from place to place. I used the general nature of the upper, middle and lower Revett Formation to help place measured sequences into a broad context. Therefore, a section that consisted of packages of quartzite that alternate with packets of siltite would be placed into the upper Revett Formation, whereas a section that contained dominantly siltite or argillite would be classified as middle Revett. The Revett/St Regis contact also provided a useful datum that appears to be traceable over large areas.

One of the difficulties in stratigraphic studies is to identify the significance of faults. In this study, I relied on published geologic maps to provide information on surface faults, and unpublished mine maps for underground work and core logging. Significant faults and structures were noted, and where possible, I attempted to assess their offsets. However, due to the structural complexity of the Coeur d'Alene district, it is likely that I overlooked faults that juxtapose different stratigraphic units. I only hope that this has not led to major miscorrelations.

Stratigraphy of the Revett Formation south of the Osburn Fault

Stratigraphy of the upper Revett Formation south of the Osburn Fault

The upper Revett Formation contains seven subunits south of the Osburn fault (Figure 10): LQ (lower quartzite), LS (lower siltite), MQ (middle quartzite), US1 (first upper siltite), UQ1 (first upper quartzite), US2 (second upper siltite), and UQ2 (second upper quartzite). In the Silver Belt, these subunits form an upper Revett member that is 450 to 500 m thick. In general, the upper Revett becomes finer-grained towards the center of the Silver Belt, through loss of quartzite and gain of siltite and argillite. From the Crescent mine to the west, the upper Revett thickens to approximately 650 m by the addition of quartzite at the lower end of the section, and therefore the Silver Belt subunits cannot be applied in this region. To the east of the Silver Belt, the upper Revett is over 550 m thick in the Reindeer Queen area, which is also thicker than the Silver Belt sections.

The upper Revett Formation shows significant changes in color and redox state in the area south of the Osburn Fault. Oxidized strata are purple to lavender and contain magnetite or hematite. Reduced strata are green to white and do not contain magnetite or hematite. In general, the contact between oxidized and reduced strata lies near the base of the lowest unit of thin-bedded argillite. Above this, rocks are commonly oxidized, but reduced strata may form a significant or even major portion of the section. At the Bunker Hill and Crescent mines in the west, and at the Caladay mine in the east, the upper Revett is totally reduced. Towards the center of the Silver Belt, however, oxidized beds increase at the expense of reduced beds, and lavender rocks occur in US1 at the Coeur, Consolidated Silver and Sunshine mines. The cross-cutting nature of these color changes demonstrates that color is not a reliable contact criterion.

Stratigraphy of the middle Revett Formation south of the Osburn Fault

Few workings have penetrated much of the middle Revett Formation south of the Osburn fault, so this unit is poorly known, and the conclusions here are tentative.

The middle Revett south of the Osburn fault appears to be 400 to 450 m thick, based on cross sections from the Big Creek area and the West Fork of Pine Creek. The lesser figure from the West Fork of Pine Creek may reflect thickening of the upper Revett and concomitant thinning of the middle Revett to the west from the Big Creek area. Alternatively, these thickness variations may reflect unrecognized faulting.

At the Consolidated Silver mine, DDH 54-2 penetrated 430 m (stratigraphic thickness) of middle Revett before passing through the axis of the Big Creek anticline. Thicknesses obtained from this hole are somewhat unreliable because the hole crosses several major structures. Nonetheless, the middle Revett may contain two subdivisions: (1) an upper unit that is dominated by siltite and (2) a lower unit that contains significant amounts of quartzite (Plate 29). Reconnaisance observations at Big Creek and the Sunshine mine (Plate 54) also indicate that the middle Revett contains significant amounts of quartzite.

Stratigraphy of the lower Revett Formation south of the Osburn Fault

Although we know little about the middle Revett Formation south of the Osburn fault, we know less about the lower Revett in this area. At Silver Hill, where I have walked through the entire Revett section, the Revett Formation is approximately 1650 m thick. If the upper Revett in this area is approximately 470 m thick, and the middle Revett is approximately 440 m thick, then the lower Revett is approximately 740 m thick. Reconnaissance observations suggest that the lower Revett has more quartzite and less siltite than the upper Revett, and that the lower Revett has a higher percentage of vitreous and subvitreous quartzite than the upper Revett. At Big Creek, the top of the lower Revett forms the distinct, bold, white outcrop near the road (Figure 4). In fact, the top of the lower Revett appears to contain the most vitreous quartzite in the entire Revett Formation south of the Osburn fault.

Stratigraphy of the Revett Formation north of the Osburn Fault

The Revett Formation is very different to the north of the Osburn fault, with much thinner stratigraphic units than to the south of the fault. North of the Osburn fault, there is 45 to 120 m of upper Revett, 75 to 120 m of middle Revett and approximately 450 m of lower Revett (Figure 11).

Stratigraphy of the upper Revett Formation north of the Osburn Fault

The upper Revett Formation north of the Osburn fault contains five distinct subunits: LQ (lower quartzite), LS (lower siltite), MQ (middle quartzite), US (upper siltite), and UQ (upper quartzite) (Figure 11). These subunits occur widely throughout northern Idaho and western Montana, where they commonly form a 60 to 90 m thick upper Revett (Hayes, 1983; White and others, 1984).

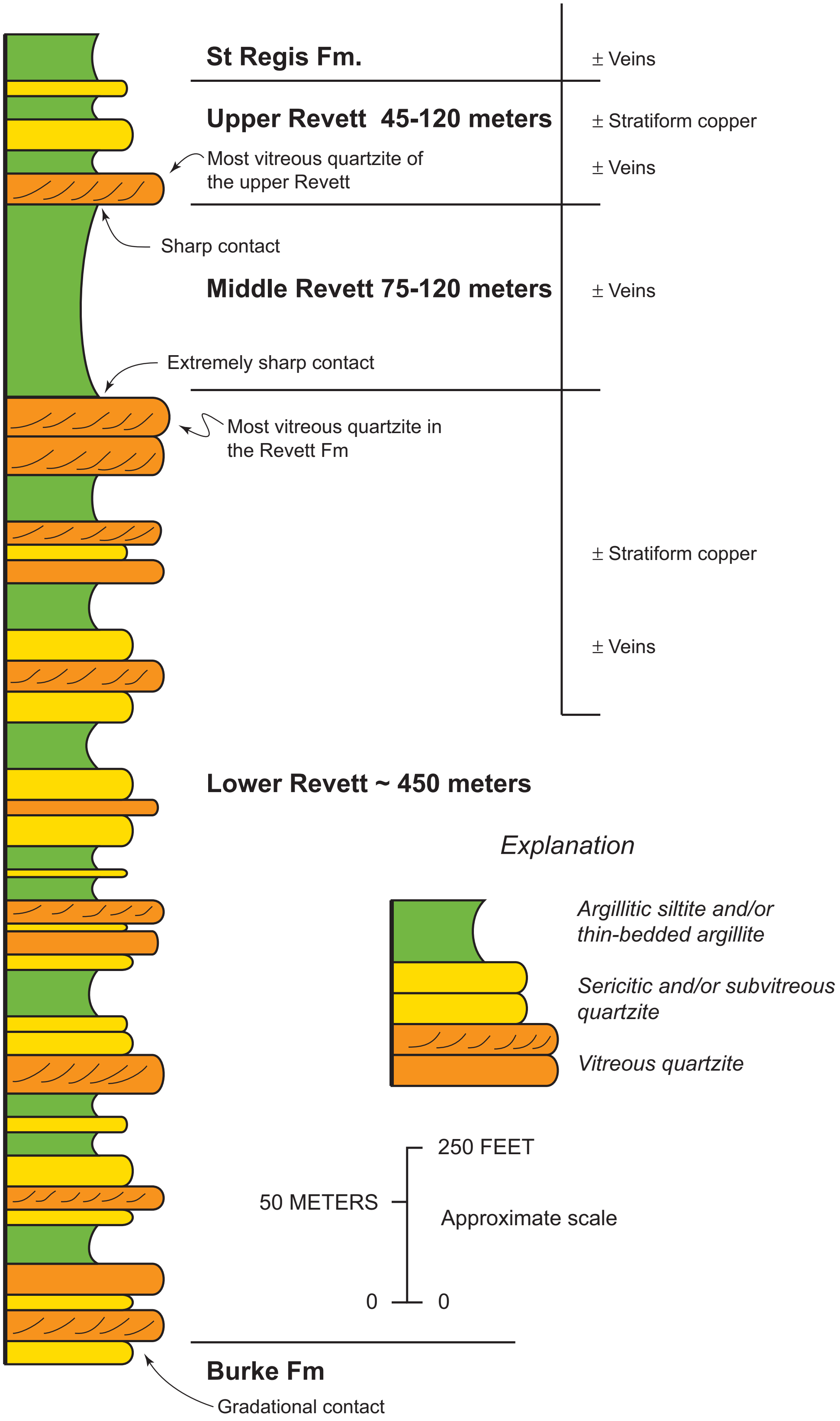

Figure 11. Generalized stratigraphic section of the Revett Fm north of the Osburn fault.

The upper Revett Formation is approximately 120 m thick at the Two Mile Creek, Allied Silver, Lucky Friday, and Idaho-Montana Silver properties. These unusually thick sections of Revett contrast markedly with the 45 m of upper Revett at Military Gulch, and with the more “normal” thicknesses of 60 to 90 m of upper Revett elsewhere.

The upper Revett Formation is totally reduced at Two Mile Creek, Allied Silver, Lucky Friday and Military Gulch sections. At the Idaho-Montana Silver property, however, the top 15 m of the upper Revett contain magnetite, and therefore are chemically oxidized.

Stratigraphy of the middle Revett Formation north of the Osburn Fault

In most places in western Montana and northern Idaho, the middle Revett is approximately 90 to 150 m thick and dominated by siltite (White, 2000; Figure 11). However, thin-bedded argillite and quartzite are locally important constituents of the middle Revett in the Coeur d’Alene district and elsewhere. For example, at the Lucky Friday mine and the Allied Silver property, quartzite commonly occurs in the middle Revett. At the Idaho-Montana Silver property, this quartzite is absent, and the middle Revett locally contains thin-bedded argillite.

In the Coeur d’Alene district, north of the Osburn Fault, the middle Revett is approximately 120 m thick at the Lucky Friday, Allied Silver, Two Mile Creek and Idaho-Montana Silver sections, which is slightly greater than the average thickness elsewhere in northern Idaho and western Montana. At Military Gulch, however, the middle Revett thins to approximately 60 m.

The middle Revett contains only reduced strata at the Lucky Friday, Allied Silver and Two Mile Creek sections. At the Military Gulch and Idaho-Montana Silver sections, however, the middle Revett contains significant intervals that are lavender or contain magnetite, and therefore are chemically oxidized.

Stratigraphy of the lower Revett Formation north of the Osburn Fault

The lower Revett is typically 400 to 450 m thick in western Montana and northern Idaho, and consists of thick intervals of quartzite with thinner intervals of siltite (Figure 11). At Two Mile Creek and Blossom Lakes, the lower Revett exhibits a coarsening upwards sequence. Towards the base of the section, sericitic quartzite is the dominant lithology. Near the middle portion of the lower Revett, subvitreous quartzite becomes the most abundant rock type. At the top of the lower Revett, vitreous quartzite is conspicuous and abundant, commonly forming large bold cliffs. At the type area of Revett Lakes, which is adjacent to the Blossom Lakes section, the lower Revett forms the bold outcrops that occur in the cirque walls. These exposures led to the concept of the Revett as a single, thick quartzite unit. In some places north of the Osburn fault, the lower Revett has been mapped as the entire Revett, and the middle and upper Revett have been included in the St Regis Formation.

Discussion

The Revett Formation has radically different thicknesses on opposite sides of the Osburn fault, with some units showing over one order of magnitude of thickness change. Consequently, the correlations of upper, middle and lower Revett across the Osburn fault must be regarded as tenuous. However, three lines of evidence indicate that these correlations may be valid. (1) On both sides of the Osburn fault, the stratigraphic sequences within the three members of the Revett Formation are similar. Thus, quartzite dominates the lower Revett on both sides of the Osburn fault, siltite dominates the middle Revett, and the upper Revett contains subequal amounts of siltite and quartzite on both sides of the fault. (2) The uppermost quartzite of the lower Revett is the most vitreous quartzite in the entire Revett Formation on both sides of the Osburn fault. (3) The contact between the middle and lower Revett is extremely sharp on both sides of the Osburn fault. In some places, such as Military Gulch, this contact is clearly an erosional unconformity. If this were a widespread unconformity, it would strengthen correlations on a regional scale. However, this remains a tentative hypothesis that needs further testing.

Regardless of whether or not members of the Revett actually correlate across the Osburn fault, this structure coincides with the greatest differences in stratigraphic thickness in the Revett Formation. Winston (1986) proposed that the Osburn fault in the Coeur d'Alene district follows a Proterozoic growth fault that he labels the Jocko line, and the data presented here support this interpretation.

Paleocurrent data from the Revett Formation in the Coeur d'Alene mining district indicate that the dominant paleocurrent direction was to the north or northeast. There are no paleocurrent data indicating that sediments were being shed to the south off an escarpment, and therefore, if the Jocko line was active during sedimentation, it probably had little or no topographic relief.

Conclusions

Six different rock types occur in the Revett and lower St Regis Formations: vitreous quartzite, subvitreous quartzite, sericitic quartzite, blocky siltite, argillitic siltite, and thin-bedded argillite. These rock types are distinguished by their color, hardness, grain size, sorting, bed thickness, and sedimentary structures. Of these parameters, bed thickness, sedimentary structures, and sorting are the most reliable in the field.

The Revett Formation contains three informal members. The lower Revett Formation is dominated by quartzite, but also contains intervals of siltite. The middle Revett consists predominantly of siltite, though quartzite and argillite locally form significant intervals. The upper Revett consists of intervals of quartzite that alternate with intervals of siltite and/or thin-bedded argillite. The lowest portion of the St Regis Formation may consist of siltite or thin-bedded argillite, depending on the locality.

Following the suggestion of Hayes (1983), I place the contact between the Revett and St Regis Formations at the top of the highest coset of thick sets of quartzite. This placement has the effect of including most of what has historically been considered to be the Revett/St Regis transition zone in the upper Revett south of the Osburn fault, and in the upper and middle Revett north of the Osburn fault. I define the Revett/St Regis transition zone as the stratigraphic interval that contains both thin-bedded argillite and quartzite. South of the Osburn fault, in the Silver Belt, this interval cross-cuts stratigraphy, being thickest in the vicinity of the Consolidated Silver mine, and pinching out to the east and west of this mine. North of the Osburn fault, this transition zone exists only at the Idaho-Montana Silver property.

The change between chemically oxidized and chemically reduced strata closely follows the base of the lowest interval of thin-bedded argillite, and cross-cuts stratigraphy in the Silver Belt south of the Osburn fault. North of the Osburn fault, a tongue of oxidized rocks occurs in the middle Revett at the Idaho-Montana Silver property and at Military Gulch.

Based on stratigraphic thickness and facies changes within the Revett Formation, the Coeur d'Alene mining district can be subdivided into four blocks: the Bunker Hill block, the Silver Belt block, the Lucky Friday block, and the western Montana copper sulfide belt block. South of the Osburn fault, in the Silver Belt, the 450 to 500 m thick upper Revett can be subdivided into 7 distinct subunits: LQ (lower quartzite, LS (lower siltite), MQ (middle quartzite), US1 (first upper siltite), UQ1 (first upper quartzite), US2 (second upper siltite), and UQ2 (second upper quartzite). These subunits extend across the Silver Belt, and can be identified in outcrop exposures south of the Osburn fault. Within this area, two distinct facies changes occur. (1) The upper Revett fines towards the middle of the Silver Belt by the addition of siltite, thin-bedded argillite, and sericitic quartzite at the expense of vitreous and subvitreous quartzite. (2) The upper Revett appears to fine to the north in a similar manner.

To the west of the Silver Belt lies the Bunker Hill block, where the upper Revett is approximately 640 m thick, and contains intervals of vitreous quartzite that alternate with intervals of siltite. The stratigraphy of the Revett Formation in the Crescent mine is transitional between that exposed in the Bunker Hill and Silver Belt blocks because although the upper Revett is approximately 640 m thick, most of the quartzite is sericitic or subvitreous.

North of the Osburn fault, the upper Revett contains five distinct subunits: LQ (lower quartzite), LS (lower siltite), MQ (middle quartzite), US (upper siltite), and UQ (upper quartzite). Both the middle and upper Revett are approximately 120 m thick on the Lucky Friday block. To the north and northeast, on the western Montana copper sulfide belt block, the upper Revett thins to 45 to 90 m, and the middle Revett thins to 60 to 110 m.

Recognition of the stratigraphic sequence in these four blocks should facilitate local mapping as well as regional correlations. Comparison of these stratigraphic horizons with former mine production records can target future exploration into the most favorable stratigraphic horizons.

These four blocks may be bounded by growth faults, although structural juxtaposition or differential compaction may account for some of the observed thickness changes. The most significant thickness changes in the Revett Formation in the Coeur d'Alene mining district occur across the Osburn fault, coinciding with the location of the proposed Jocko line Precambrian growth fault (Winston, 1986).

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