Geologic setting, genesis, and potential of the Rusty Springs Ag-Pb-Zn-Cu property, northern Yukon (NTS 116K/8 and K/9)

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ABSTRACT

Despite many years of exploration and relatively limited success, the Rusty Springs prospect retains considerable potential for a large-tonnage deposit. The property lies within the east-vergent Taiga-Nahoni fold belt, occurring in the core of a structural culmination exposing host dolostones of the Lower and Middle Devonian Ogilvie Formation. Mineralization occurs in stratabound and discordant zones along the contact with the overlying Devono-Mississippian unnamed shale. Various deposit models, ranging from Mississippi Valley-type to epithermal vein-type have been employed. Poor exposure and relatively deep weathering, resulting from the lack of Pleistocene glaciation, account for the lack of consensus with regard to genesis. Evidence points to the potential for a high-temperature, carbonate-hosted massive sulphide deposit (manto-chimney complex). The great extent of mineralized and altered rocks, together with their stratabound nature, significant thickness, local high grades, and potential for supergene enrichment, suggest that Rusty Springs remains an attractive drill-oriented exploration target.

RÉSUMÉ

Malgré les minces succès obtenus après plusieurs années d'efforts d'exploration, l'indice de Rusty Springs présente un très bon potentiel pour un gisement de tonnage important. La propriété est située à l'intérieur de la ceinture de plissement Taiga-Nahoni de vergence est et se retrouve dans le coeur d'une culmination structurale qui expose les dolomies de la Formation d'Ogilvie du Dévonien inférieur à moyen. La minéralisation se présente en zones stratiformes et discordantes le long du contact de la Formation d'Ogilvie avec le shale Dévono-Mississipien sus-jacent (non nommé). On a tenté d'appliquer plusieurs types de modèles génétiques variant du type Mississipi Valley jusqu'au modèle des veines épithermales. La rareté des affleurements et une altération météorique relativement profonde due à l'absence de glaciation Pleistocène expliquent l'absence de consensus en ce qui concerne la genèse de la minéralisation. Les observations indiquent un potentiel pour un gisement du type sulfures massifs de haute température dans les roches carbonatées (complexe de cheminées du type Manto). La grande étendue de la minéralisation et des roches altérées combiné avec leur nature stratiforme, leur grande épaisseur, la présence par endroits de hautes teneurs ainsi que la possibilité d'un enrichissement supergène suggèrent que Rusty Springs demeure une cible attrayante pour les forages d'exploration.

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INTRODUCTION

The Rusty Springs prospect is an Ag-Pb-Zn-Cu occurrence of enigmatic origin. In spite of limited success during considerable exploration over the past 25 years, the mineralizing system at Rusty Springs still holds significant potential. Recent general interest in Rusty Springs and nearby properties has been heightened due to its location near the boundary of the Fishing Branch protected area, a proposed wilderness area in the process of being excluded from mineral claim staking. This paper reviews previous geological work on the property and discusses the genesis of mineralization. It also addresses the potential for further exploration, both on the property and in surrounding areas, a potential which is still considered high. The basis for discussion includes work undertaken in 1999, which is also summarized herein. The work included three diamond drill holes for a total of 317 m, as well as some reconnaissance work and re-mapping (at 1:50 000 scale) of the area immediately surrounding the property.

LOCATION, ACCESS, AND PHYSIOGRAPHY

Rusty Springs is located in the northern Ogilvie Mountains of northwestern Yukon, near the headwaters of the Yukon and Porcupine rivers (Fig. 1). It is located approximately 8 km south of the Arctic Circle, 29 km east of the Alaska border, and 115 km south of the village of Old Crow. Relief in the Rusty Springs area is on the order of 1000 m, with the highest point in the surrounding mountains at about 1500 m. Summits and ridges are generally rounded and subdued, and the valleys are broad (Fig. 2) and V-shaped, as the area lies in that part of the Yukon which was not glaciated during Pleistocene time.

Access to the property is via aircraft or by winter road. An all-weather, 600-m airstrip was completed in 1996. The nearest staging areas are approximately 150 to 200 km away along the Dempster Highway, near Eagle Plains. The winter haulage road, nearly 200 km in length, leads from Mile 123 (Ogilvie Crossing) on the Dempster Highway (Fig. 1).

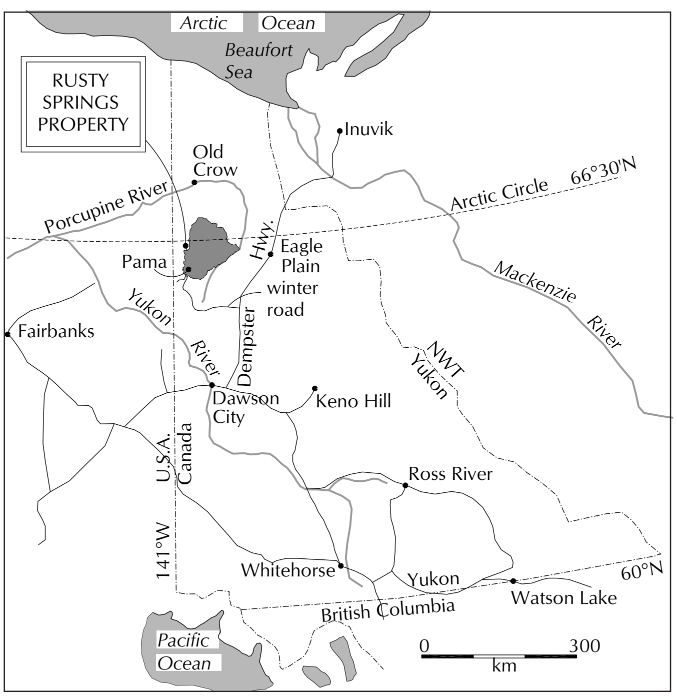


Figure 1. Location map of Rusty Springs property; shaded area shows location of proposed Fishing Branch Protected Area.

EXPLORATION HISTORY

The Rusty Springs property was first staked in 1975, after investigation of deep, red-orange springs and seeps in the valley of Carrol Creek led to the discovery of nearby silver, lead, zinc, and copper mineralization; the rusty seeps were first noted during petroleum exploration in the area. Since the discovery, the property has been the focus for nearly $5 million of exploration, including 10 separate drill campaigns in 2 major phases (1975-83 and 1994-96) totalling over 11,000 m of drilling in 123 holes (see Appendix).

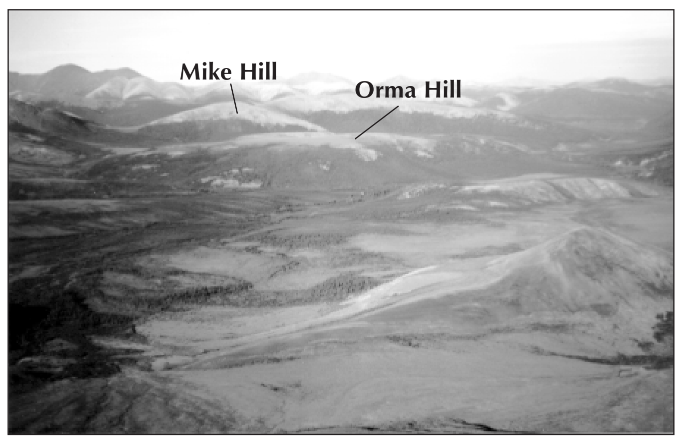


Figure 2. *View eastward across the core of the Porcupine-Rusty Springs anticlinorium, showing rounded hills, broad valleys, and poor exposure typical of the area. Mineralization occurs mainly on the two low hills in the middle ground: Orma Hill (to right, smaller and lower) and Mike Hill (larger, somewhat higher). Hill in right foreground is underlain primarily by limestone of Carboniferous and Permian (?) age (Ettrain and Jungle Creek formations), while the low-lying area between is underlain by relatively recessive Devono-Mississippian, fine-grained clastic rocks. Ridges immediately behind Mike Hill are also underlain by Ettrain and Jungle Creek formations; those on the skyline consist of Early to Late Proterozoic siliciclastic rocks (darker colour) and Late Cambrian to Early Devonian dolomite (lighter colour).*

Exploration has mainly targeted high-grade silver, lead, copper, and zinc mineralization within brecciated, and quartz- and carbonate-cemented and veined dolomite. It has been based on several genetic models, developed in part, through research by geology students employed on the property, and working on B.Sc. theses (e.g., Schoel, 1978; Hansen, 1979; Bankowski, 1980a). At various stages of exploration, models used to help guide exploration included Mississippi Valley-type (MVT); Irish Plains-type (carbonate-hosted exhalative, Bankowski 1980a); epithermal-type (veins and/or hydrothermal replacement along a karsted surface, with supergene enrichment); and manto-chimney-type (high-temperature, carbonate-hosted massive sulphides). Direct targeting of drill holes utilized various techniques, including prospecting, geological mapping, geochemistry and geophysics (see Appendix). Many of the drill programs were plagued by drilling problems, such as poor recoveries in the strongly oxidized and leached mineralized intervals, or loss of water pressure in blocky brecciated zones with abundant open space. Drilling was often slow and costly in resistant siliceous 'chert' horizons that cap the mineralized stratigraphy. Trenching was also challenging, mainly because of deep permafrost and deep, soliflucted overburden which predominate in unglaciated parts of the Yukon.

REGIONAL GEOLOGICAL SETTING

The area mapped lies within the northernmost part of the Cordilleran orogenic belt, known locally as the Taiga-Nahoni fold belt. In this belt, Precambrian to Cretaceous, predominantly sedimentary rocks of the eastward- and northward-tapering North American miogeocline were deformed in latest Cretaceous to Tertiary time (Fig. 3; Norris, 1996; Lane, 1998). The area was first mapped by Norris (1981), who outlined a

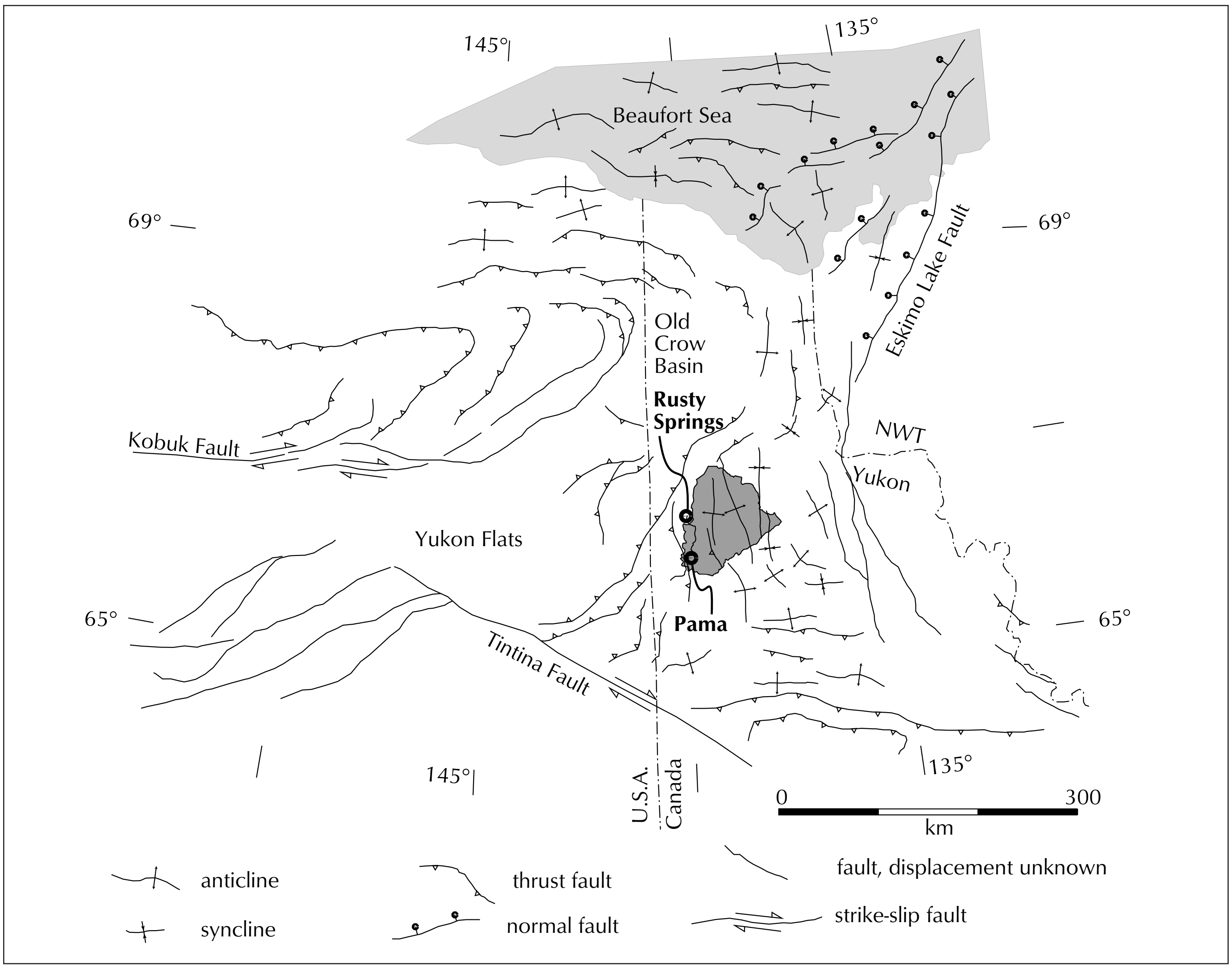


Figure 3. *Major structures of northwesternmost Canada and adjacent Alaska, showing location of Rusty Springs and Pama properties, as well as proposed Fishing Branch Protected Area (shaded) in the northern Ogilvie Mountains (after Lane, 1998).*

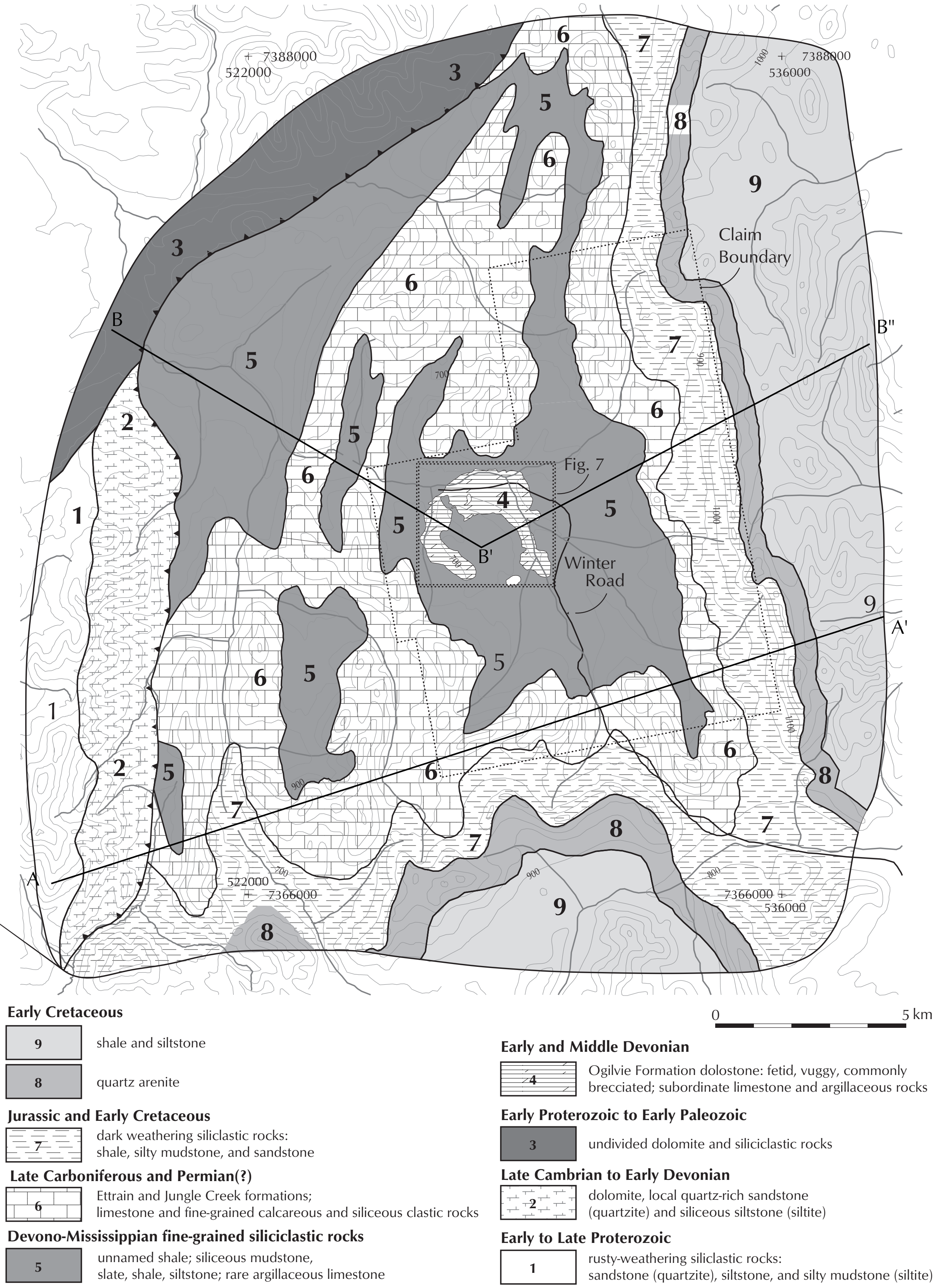


Figure 4. *Geology of the Rusty Springs property. Contour interval is 100 m. A-A′ and B-B′-B′′ mark the location of cross-sections in Figure 6.*

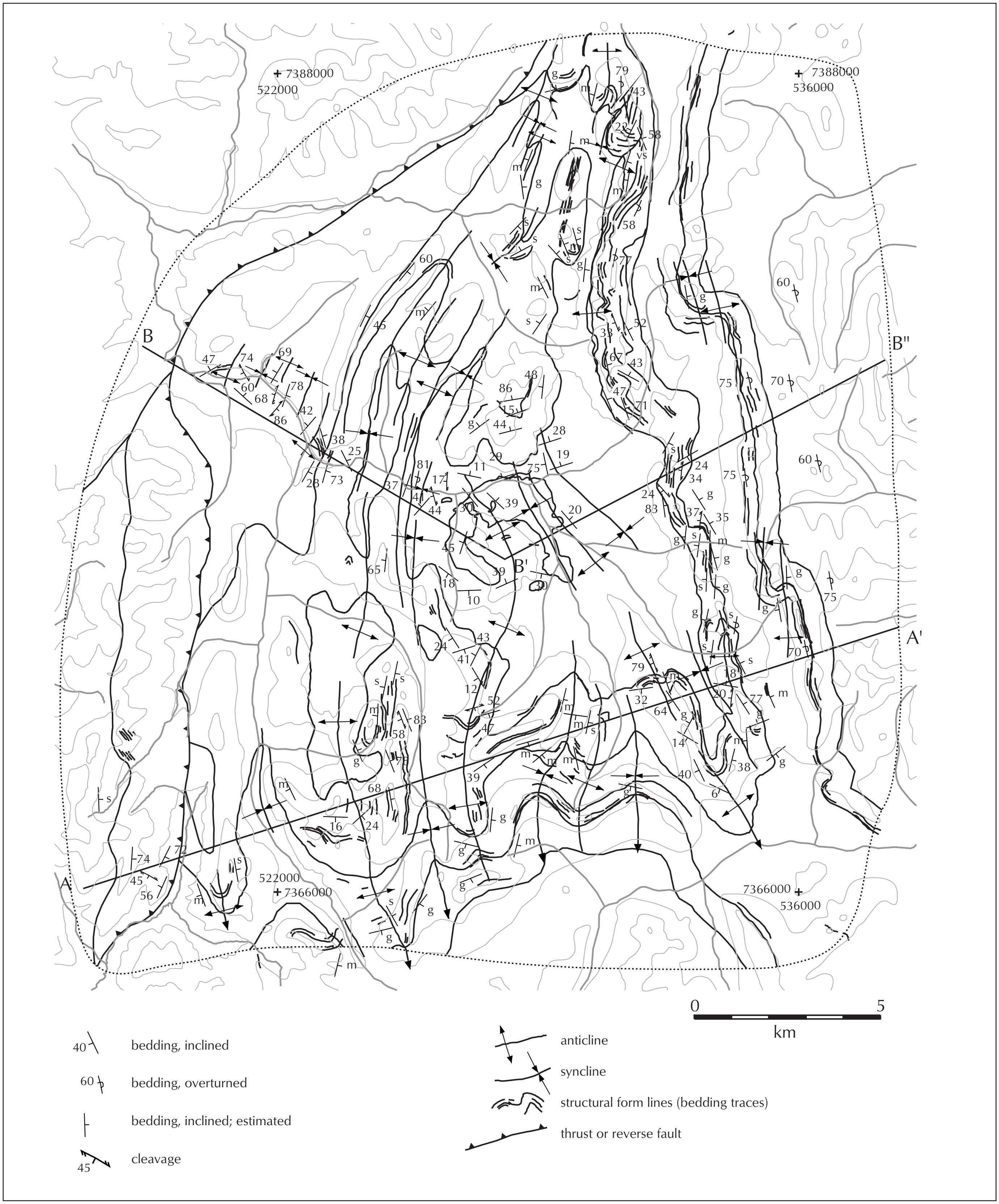
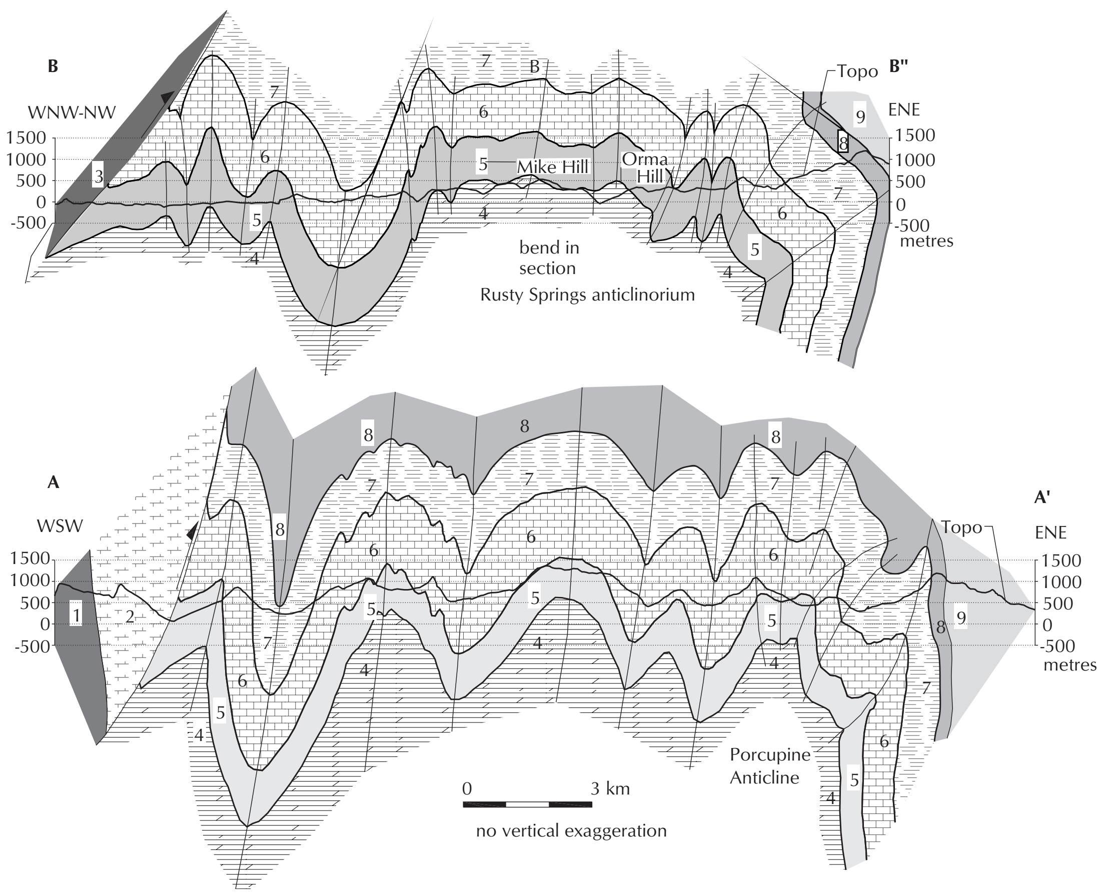


Figure 5. *Structural map of the Rusty Springs property; bedding orientations estimated from a distance: g=gentle, m=moderate, s=steep; contour interval 200 m and A-A′ and B-B′-B′′ mark the location of cross-sections in Figure 6.*

structural culmination, in part coincident with his Porcupine Anticline, cored by rocks of the Lower and Middle Devonian Ogilvie Formation. Norris (1981) shows stratigraphically lower rocks of Early Paleozoic, Cambrian, and Proterozoic age bounding the west side of the culmination and brought up by mainly west-vergent contractional faults.

PROPERTY GEOLOGY

Nine map units, ranging in age from Proterozoic to Cretaceous, correspond largely with those mapped by previous workers (e.g., Chernoff, 1976; Kirker, 1980a; Tempelman-Kluit, 1981; Fig. 4), but improved bedding control (Fig. 5) yields a significantly different structural interpretation (see cross-sections, Fig. 6). Ages of the map units were taken mainly from Norris (1981, 1996). Exposure is generally poor near the valley bottom and consequently the focus for property-scale geologic mapping was on the rocks exposed on surrounding ridges. The geology in the immediate vicinity of the mineralized and altered zones at Rusty Springs, which outcrop at lower elevations in the vicinity of two lower hills, named the Mike and Orma hills, was examined briefly; a compilation map and cross-section are shown in Figures 7 and 8, respectively.



Early Cretaceous

9 — shale and siltstone

8 — quartz arenite

Jurassic and Early Cretaceous

7 — dark weathering siliclastic rocks: shale, silty mudstone, and sandstone

Late Carboniferous and Permian(?)

6 — Ettrain and Jungle Creek formations; limestone and fine-grained calcareous and siliceous clastic rocks

Devono-Mississippian fine-grained siliciclastic rocks

5 — unnamed shale; siliceous mudstone, slate, shale, siltstone; rare argillaceous limestone

Early and Middle Devonian

4 — Ogilvie Formation; dolostone: fetid, vuggy, commonly brecciated; subordinate limestone and argillaceous rocks

Early Proterozoic to Early Paleozoic

3 — undivided dolomite and siliciclastic rocks

Late Cambrian to Early Devonian

2 — dolomite, local quartz-rich sandstone (quartzite) and siliceous siltstone (siltite)

Early to Late Proterozoic

1 — rusty-weathering siliclastic rocks: sandstone (quartzite), siltstone, and silty mudstone (siltite)

Figure 6. *Geologic cross-sections, Rusty Springs property; see Figure 4 and 5 for location of sections.*

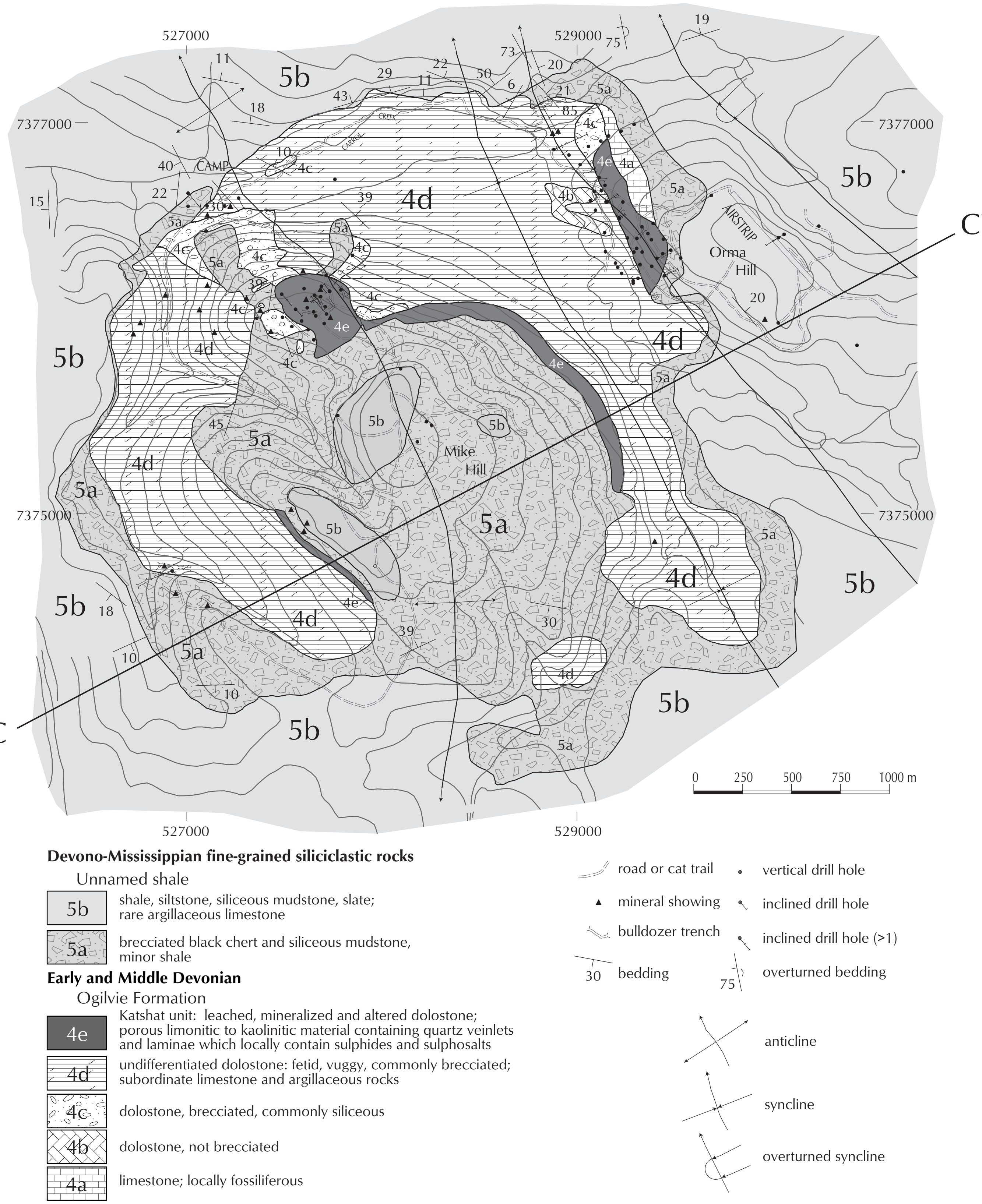


***Figure 7.** Geology of the core of the Rusty Springs anticline, Mike and Orma hills (location of map shown in Figure 4; geology mainly after Hansen,1979; Hansen and Bankowski, 1979; and Aussant, 1983); contour interval 20 m. C-C' is location of cross-section in Figure 8.*

LOWER TO UPPER PROTEROZOIC ROCKS

Rusty-weathering, fine-grained sandstone (quartzite), interbedded with maroon and local green siltstone and silty mudstone (siltite) occurs in a northerly trending belt in the southwesternmost corner of the area mapped (Fig. 4). The siliciclastic rocks, which were only briefly examined, appear to be conformable with steeply east-dipping Lower Paleozoic dolostone and quartz-rich sandstone to the east.

LOWER PALEOZOIC ROCKS

Like the older rocks which they appear to overlie conformably, rocks of probable Late Cambrian through Early Devonian age occur in a northerly trending belt along the west margin of the map area (Fig. 4). The Lower Paleozoic rocks consist of white-weathering dolostone, rusty-weathering quartz-rich sandstone (quartzite), and siliceous fine-grained clastic rocks, including green and maroon siltstone and silty mudstone (siltite). Rocks of similar general appearance occur to the north, but were neither examined nor differentiated from the older siliciclastic rocks. The Lower Paleozoic rocks are inferred to be in thrust contact with younger Paleozoic and Mesozoic rocks to the west, although a down-to-the-east normal fault was mapped along trend to the south by Norris (1981). The presence of the inferred thrust is supported by the marked easterly vergence of folds in the area (see Fig. 6).

LOWER AND MIDDLE DEVONIAN OGILVIE FORMATION

Pale grey-weathering, dark grey dolostone and subordinate limestone and argillaceous rocks of the Ogilvie Formation underlie the central part of the Rusty Springs property in the core of the Porcupine-Rusty Springs anticlinorium (Figs. 7, 8). They form common talus slopes on the flanks of Orma and Mike hills, but outcrop is scarce, even on roads and cat trails. Dolostone is fetid, and commonly brecciated (Fig. 9), veined, and/or vuggy. Breccia cements consist mainly of dolomite and sparry calcite with local quartz; vugs are commonly lined with calcite and quartz, and veinlets are of similar mineralogy. Another common constituent of Ogilvie Formation breccias is pyrobitumen. Pyrobitumen is commonly intergrown with dolomite cements and is always associated with quartz and/or calcite spar (Kirker, 1982); it also locally coats vugs. Dolomite crystals in dolostone are typically fine- to medium-grained and locally coarse-grained, with coarser grained varieties typically

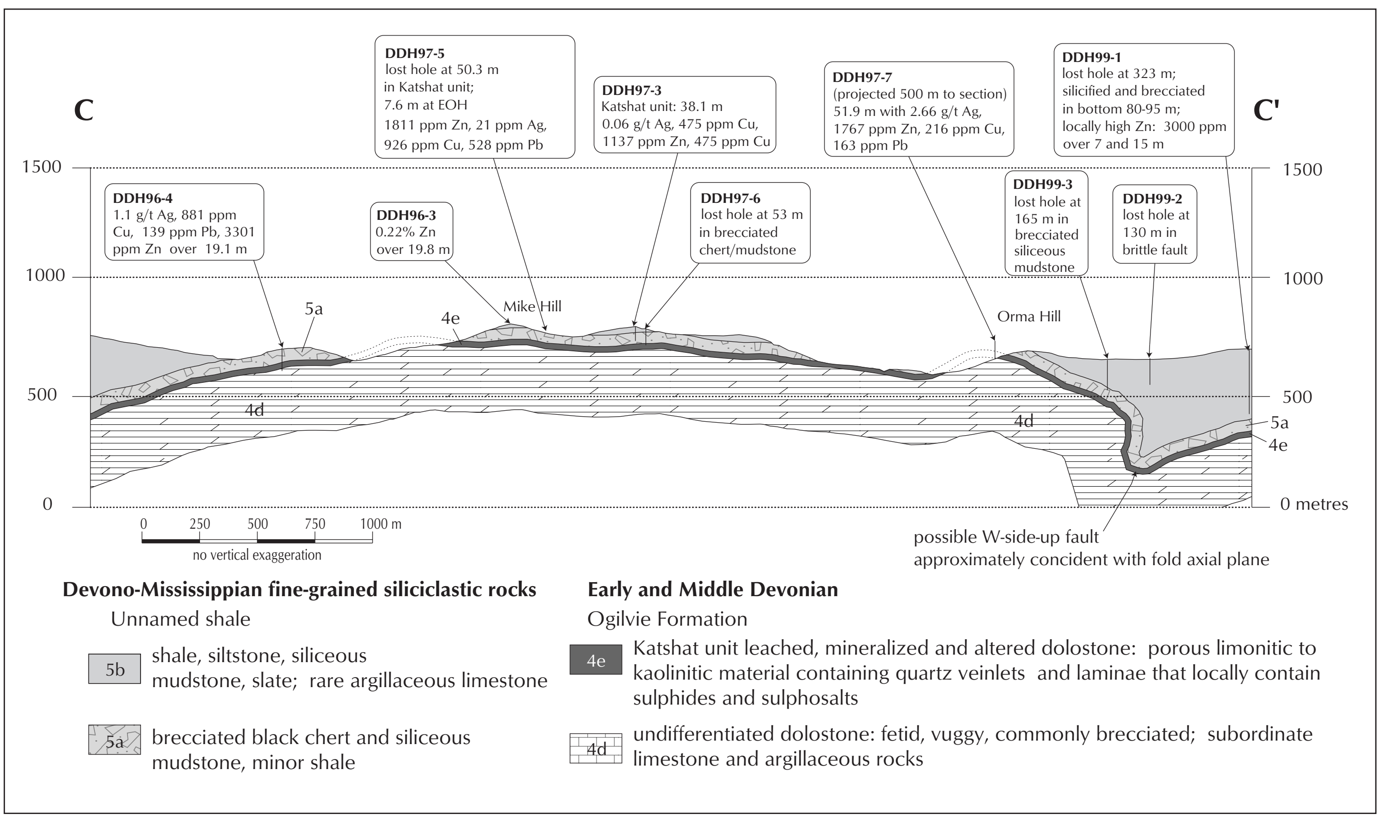


Figure 8. *Geologic cross-section through Mike and Orma hills, showing most of the drill hole intersections of the mineralized 'Katshat unit', as well as drill hole control on its probable location at depth toward the east side of the property, mainly from 1999 drilling; see Figure 7 for location of section.*

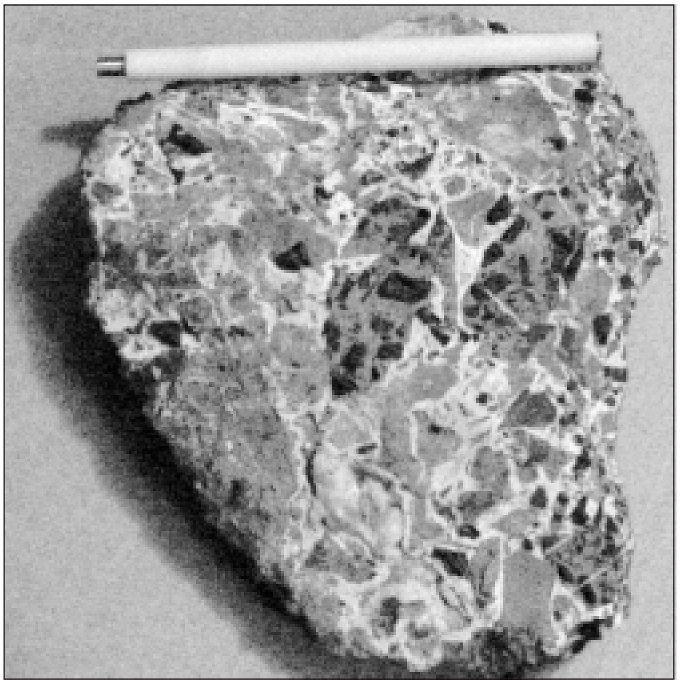


Figure 9. *Dolostone breccia from Mike Hill. Breccia is polyphase and cement is sparry calcite with local quartz (higher relief).*

weathering a paler grey colour. Locally, weakly dolomitized limestone contains recognizable brachiopods, ostracods, corals, and crinoids (Hansen, 1979; Davis and Aussant, 1982), although no diagnostic fossils have been reported. Float boulders and the few outcrops of the Ogilvie Formation suggest that it is poorly stratified. However bedding is more apparent in diamond drill core, particularly where brecciation is less intense. Bedding to core axis angles typically suggest that the strata in the vicinity of Mike and Orma hills are dipping gently. Mainly on the basis of their contained fauna, Hansen (1979) interpreted the dolostones of the Ogilvie Formation as a shallow water 'reefal' unit, while Kirker (1982) suggested a shallow-water shelf environment. The base of the Ogilvie Formation at Rusty Springs is not exposed, but a drill hole between Mike and Orma hills penetrated about 210 m (probable true thickness) of dolostone, with local interbedded shale, and rare limestone and quartzite (Chamberlain, 1986).

At the top of the Ogilvie Formation at Rusty Springs is the informally named 'Katshat unit,' a recessive, gossanous oxide- and clay-rich unit which corresponds to a significant degree with the mineralized zones on the property. In general, the unit appears to be stratabound, separating the dolostone from overlying siliciclastic rocks, but in detail, its contacts are highly irregular. The Katshat unit most likely represents altered and mineralized Ogilvie Formation limestone–it is discussed in more detail below.

DEVONO-MISSISSIPPIAN FINE-GRAINED SILICICLASTIC ROCKS

Disconformably overlying the Ogilvie Formation are siliceous mudstone, slate, shale, siltstone, and rare limestone of probable Devono-Mississippian age. Norris (1981) assigned these rocks to the Hart River Formation (Early and Late Carboniferous age). However they are more likely correlative with fine-grained clastic rocks, such as the Upper Devonian Canol Formation, the 'unnamed shale,' the Upper Devonian and Lower Carboniferous Ford Lake shale (Norris, 1981, 1996), and the Kayak Formation (Richards et al. ,1996), since the Hart River Formation consists mainly of limestone (Norris, 1981, 1996). Herein the rocks have been assigned to the 'unnamed shale.'

The lowermost rocks in the sequence, best exposed on Orma and Mike hills and referred to locally as black 'chert,' are perhaps more accurately referred to as a silicified and/or siliceous mudstone. Thin laminations and recrystallized radiolaria are locally preserved (Hansen, 1979). The siliceous rocks are up to 40 m thick (Hodder, 1997) and are commonly veined and brecciated; veins and breccia matrices consist mainly of quartz, calcite, and dolomite. The brecciated siliceous rocks appear in most places to cap the mineralized Katshat unit of the uppermost Ogilvie Formation. Black siliceous (?) fragments are locally a component of the dolostone breccias that commonly comprise upper Ogilvie Formation rocks beneath the Katshat unit.

Up-section from the siliceous rocks, and comprising the bulk of the rocks assigned to the unnamed shale, are relatively recessive pyritic, carbonaceous shale, mudstone, silty mudstone, and local thin- to medium-bedded, poorly sorted, fine-grained litharenite. They are generally thinly bedded, and typically siliceous, although local calcareous shale was also noted. Local true slate and rare dark grey, fetid and laminated algal limestone occur not far above its contact with the Ogilvie Formation. Erosion of this part of the unit, which is as much as 500 m thick, has led to the broad and open drainage basin within which the Rusty Springs property is located (Fig. 2).

The transition of the fine-grained clastic sequence to the overlying mixed carbonate and clastic unit is commonly marked by the presence of thin- to medium-bedded, siliceous, fine sandy siltstone or fine-grained sandstone. These rocks are typically pale grey and locally rusty-weathered up close, but appear very dark from a distance because of a common covering of black lichen.

UPPER CARBONIFEROUS AND PERMIAN (?) LIMESTONE AND FINE-GRAINED CALCAREOUS AND SILICICLASTIC ROCKS

Medium-bedded, pale grey-weathering, medium to dark grey, sandy and locally pebbly fetid limestone and rare dolostone characterize this unit. The limestone commonly contains irregular dark grey chert nodules and occurs in several (?) horizons of amalgamated beds that are up to several tens of metres thick. They form many of the better outcrops in the area, and because of their resistant character, they underlie many of the ridges surrounding the broad upper drainage basin of Carrol Creek (Fig. 2). The upper limit of the map unit is defined by the presence of the uppermost continuous limestone sequence. Scattered float blocks of pebbly limestone commonly mark the transition from the underlying siliciclastic sequence. The pebbles are typically round to sub-round and are dominantly chert (Fig. 10). Pebbly lithologies are more common to the southwest, whereas to the east, sandy limestone is more common, and pebbly limestone occurs only locally. In addition, a limestone horizon containing abundant *in situ* corals (Fig. 11) was noted in the east but not to the south or southwest, and composite limestone horizons appear somewhat thicker (up to 50-60 m) and may contain thicker-bedded to massive layers up to 15 m thick. In spite of the predominance in outcrop of pebbly and cherty limestone, a significant portion of the map unit consists of relatively recessive, variably calcareous fine-grained clastic rocks. They include dark weathering, thin-bedded and laminated siliceous or calcareous silty mudstone, and calcareous to siliceous shale, as well as local fine-grained siliceous sandstone and siltstone. The total thickness of the limestone and associated clastic units is about 550-700 m.

The rocks of this sequence have been included previously in the Upper Carboniferous Ettrain Formation. However, Pennsylvanian and Permian fossils have been reported from within the area mapped, and so it is probably longer ranging and likely includes rocks mapped as Jungle Creek Formation by earlier workers. If so, it is difficult to distinguish Ettrain from Jungle Creek in the field.

JURASSIC AND LOWER CRETACEOUS DARK WEATHERING SILICICLASTIC ROCKS

Lying conformably above the sequence containing the resistant grey carbonates is a dark weathering package of shale, silty mudstone, and sandstone approximately 600 m thick. Included in this map unit are rocks that Norris (1981) assigned to the Jurassic and Lower Cretaceous Kingak, Porcupine River, and Husky formations. The lower part in the Rusty Springs area consists of common pale to medium-brown-weathering silty mudstone with local buff-weathering carbonate layers, and dark brown-weathering shale. Near the east-central part of the area mapped, close to its base, the sequence includes a thick (up to 46 m; Chernoff, 1976) oolitic, hematite-magnetite siliceous iron formation. Several kilometres along strike to the north, and at the same stratigraphic level, massive black carbonaceous and siliceous mudstone and silty mudstone mark the base of the unit. Similarly resistant siliceous rocks mark the upper part of the unit, which underlies many of the highest ridges in the south and east parts of the area mapped. They are very dark weathering and consist mainly of blocky weathering, medium-grained feldspathic cherty quartz arenite, and fine-grained carbonaceous siliceous litharenite.

LOWER CRETACEOUS SHALE, SILTSTONE, AND QUARTZ ARENITE

The two units bounding the east side of the map area were taken from the mapping of Chernoff (1976), who shows numerous overturned beds within their bounds. He assigned the shale, siltstone, and quartz arenite comprising the units to the

Figure 10. *Limy pebble conglomerate or pebbly limestone common to Carboniferous or Permian (?) rocks of the Ettrain or Jungle Creek formations; pebbles are predominantly chert.*

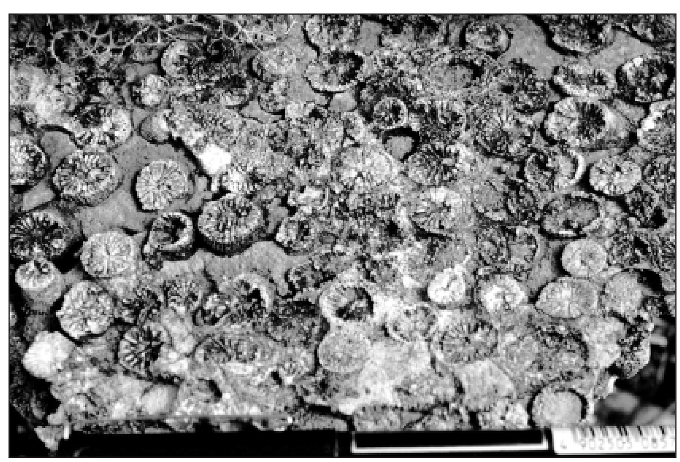


Figure 11. *Carboniferous or Permian (?) colonial corals common in limestone of the Ettrain or Jungle Creek formations in the eastern part of the map area.*

Cretaceous Marten Creek and Goodenough (*sic*) formations. Norris (1981) assigned them a Lower Cretaceous age, and included them in his 'KWC' unit and the Mount Goodenough Formation.

STRUCTURAL GEOLOGY

Folds are the dominant structural feature in the map area, and wavelengths of the typical east-vergent, open to tight and locally overturned folds are on the order of 1-5 km (Figs. 5, 6, 12). The folds occur across the crest of an approximately 20-km-wide, northerly trending and doubly plunging anticlinorium centred on the mineralized showings at Rusty Springs. The east side of this domal feature corresponds to the Porcupine Anticline of Norris (1981). Brittle faults are common on the property, and have been intersected in drill holes and interpreted from geophysical surveys and surface features (such as linear stream patterns), but none of these faults appears to offset map units at the property scale. The plunge reversal that corresponds with the mineralized area and which has been interpreted by some (e.g., Chernoff, 1976) to have been associated with a brittle fault, appears from the map patterns to be fold-related and the consequence of some deeper level structure, such as a lateral ramp.

Several property-scale cross-sections have been prepared previously, beginning with that of Chernoff (1976), and followed by Kirker (1980) and Tempelman-Kluit (1981). Chernoff (1976) shows a large-scale easterly overturned antiform, which is centred on the Rusty Springs showings and which he interprets as being cored by intrusive rocks and floored by north-trending, east-directed thrust faults. In contrast, Kirker (1980) and Tempelman-Kluit show inferred, north-trending faults, but interpret them as west-vergent contractional faults. They also show related folds with generally open geometries (Kirker 1980; Tempelman-Kluit, 1981). Cross-sections based on improved bedding control, compiled in part from previous work and benefitting from recent drill hole control, suggest that the structural setting is somewhat more akin to that shown by Chernoff (1976), in that the transport direction across the anticlinorium is toward the east. An east-directed transport direction is also more in accord with the regional sense of vergence (e.g., Fig. 3).

Figure 12. *Anticline outlined by Ettrain and/or Jungle Creek formation limestones in the southeast corner of the map area; elevation of hill is 250 m.*

Speculatively, the area may be floored by a large-scale east-vergent contractional fault, in part as envisioned by Chernoff (1976). Key to this interpretation are the steeply dipping and overturned Cretaceous rocks along the east side of the area (Figs. 4-6) mapped by Chernoff (1976). They may represent the eastern, overturned limb of the northern Porcupine Anticline, and may be floored by an inferred southern continuation of an east-vergent contractional fault shown by Norris (1981). Norris sees this fault as bounding a panel of Late Proterozoic to early Paleozoic rocks on their east side, about 15-20 km to the north-northeast. If this is the case, the doubly plunging anticlinorium underlying the Rusty Springs area may reflect the influence of a deep-seated feature, such as a lateral ramp, along the inferred contractional fault.

MINERALIZATION

Although exploration models utilized at Rusty Springs have tended to exclusively target either stratabound (e.g., Mississippi Valley-type (MVT) or Irish Plains-type) or discordant styles of mineralization (hydrothermal veins), there appears to be good evidence for both styles on the property, and they appear to be genetically related. Both styles of mineralization are found almost exclusively in the upper Ogilvie Formation and in the vicinity of the Mike and Orma hills (Fig. 7; Hansen and Bankowski, 1979). Their spatial association, similar geochemical signatures, and association with similar brecciated and dolomitized zones suggest the genetic link. Potential rests mainly with the stratabound mineralization, which may have greater thickness, much greater continuity, and can be much more readily explored.

VEIN-TYPE MINERALIZATION: THE ORMA ZONE

Mineralization at the Orma zone, on the northwest flank of Orma Hill, has been the focus for the bulk of the exploration work at Rusty Springs. Up to the 1990s, virtually all of the drilling on the property occurred there. The zone has yielded many of the highest grades in grab samples, trenches, and drill core (e.g., DDH80-1: 583 g/t Ag, 8.23% Pb, and 1.48% Cu over 6.5 m). Trenching and drilling have confirmed that it is a discontinuous vein and stockwork zone, which trends northwest and dips steeply. Vein-type mineralization also appears to be present locally at Mike Hill. However, here relatively high Zn and trace Au values commonly accompany the Ag, Pb, and Cu (Downie, 1994; e.g., DDH95-07: 518 g/t Ag, 0.77% Pb, 3.0% Cu, and 1.3% Zn over 15.3 m; see Fig. 13).

Veins consist of massive galena-tetrahedrite (tennantite?, as is suggested by elevated As:Sb ratios in some assays; Liedtke, 1980), locally up to 1.0 m thick, which assay roughly 10-50 g/t Ag. The veins are contained within a broader, commonly oxidized, mineralized and altered zone (in part, a stockwork) of up to 6 or 7 m in thickness. The altered zone typically assays 30 to 60 g/t Ag; Davis and Aussant, 1982). Alteration within Ogilvie Formation carbonates, as described by Bankowski (1980b), is characterized by silica replacement, dolomitization, local brecciation, sanding (silicic alteration?), and decomposition (supergene alteration). It is also manifest in part, as a darker grey colour of the host rocks. The margin of the altered zone has a northwest trend, subparallel to that of the mineralized zone, and it appears to terminate, or turn bedding-parallel, to the southeast at the contact with overlying siliciclastic rocks (Bankowski, 1980b). Minerals identified from the oxidized zones include smithsonite, cerussite, malachite, azurite, aurichalcite, pyrolusite, hemimorphite, plumbojarosite, gibbsite, valentinite, and natroalunite (Hansen, 1979; Kirker, 1980b); sphalerite and pyrite are also preserved locally with galena and tetrahedrite in siliceous vein and vein-breccia material.

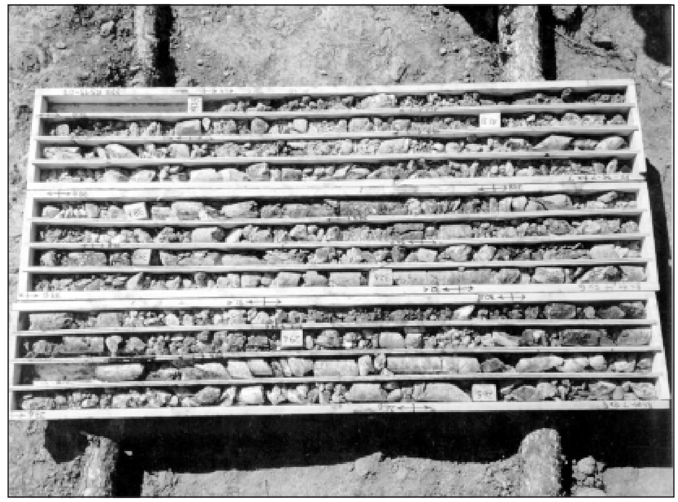


Figure 13. *Typical broken and crumbly nature of clay-rich and limonitic supergene-altered mineralization at Rusty Springs in drill core. In this case the mineralized zone represents discordant material from Mike Hill, but it is similar in general appearance and mineralogy (though of higher grade) to typical Katshat unit mineralization. DDH95-07: 15.3 m assaying 518 g/t Ag, 0.77% Pb, 3.0% Cu, and 1.3% Zn.*

STRATABOUND MINERALIZATION: THE KATSHAT UNIT

Near the end of the 1996 exploration program, stratabound mineralization along the contact between the Ogilvie Formation and overlying Devono-Mississippian siliciclastic rocks became the principal exploration target (Termuende and Downie, 1997). Almost all holes drilled in footwall Ogilvie Formation dolostone had essentially been barren. Relatively thick oxidized mineralization was previously intersected at the contact, in hanging wall siliciclastic rocks. Thus substantial potential existed for stratabound mineralization. It was also recognized that the most extensive geochemical anomalies on the property coincided with the contact, and that many drill holes targeting them had been collared in the strongly oxidized mineralized material. These holes had been plagued by poor core recoveries.

The oxidized material common to the upper contact of the Ogilvie Formation was referred to locally as the Katshat unit. It consists of strongly leached, porous limonitic to kaolinitic material with an earthy, gougy consistency, and is similar in appearance to the oxidized material surrounding discordant mineralization (e.g., Fig. 13, 14). It is typically 20 to 40 m thick, and although it appears stratabound at the property scale, in detail, it is irregular and discordant. Many of the minerals noted above as occurring in the Orma zone are also common in the Katshat unit. X-ray diffraction studies indicate that much of the

Figure 14. *Trench in Katshat unit from near top of Mike Hill, which shows typical crumbly to rubbly appearance and deep weathering profile of supergene-altered mineralized zones, with darker limonite-rich parts and paler kaolinite-rich parts. Also shown is Bob Termuende, the driving force behind exploration at Rusty Springs for nearly 25 years.*

Katshat material consists of granular Fe, Mn, Ag, Pb, Zn, Cu, Ba, Al, P as well as V oxide, carbonate, sulphate, and silicate mineral species. In addition, there are quartz veinlets and laminae locally containing sulphides and sulphosalts like those in Orma zone veins and vein stockwork (Hodder, 1997). The Katshat unit is invariably overlain by brecciated and veined siliceous or silicified mudstone and chert of probable Devono-Mississippian age which caps it and in part has protected it from erosion. It is underlain by Ogilvie Formation dolostone, also typically brecciated and veined. The Katshat unit is strongly anomalous in Ag, Cu, Pb, and Zn over broad intervals and across a wide area. For example, hole RS96-04 from the southwest part of Mike Hill had an intersection of 1.1 g/t Ag, 881 ppm Cu, 139 ppm Pb, 3301 ppm Zn over 19.1 m. In addition, hole RS96-14 from the south end of the airstrip on Orma Hill contained 1.6 g/t Ag, 1475 ppm Cu, 1321 ppm Pb, and 2701 ppm Zn over 22.2 m (see Fig. 8). Results such as these suggest the possibility of tremendous continuity and potential. The oxidized nature of the mineralization and the sub-economic grades also suggest that the preferred target be unoxidized portions of the horizon below the present and/or paleo-water table (Hodder, 1997). Unoxidized Katshat unit was the target of the latest drill program, which attempted to test the upper Ogilvie Formation to the east and south of Orma Hill (Figs. 7 and 8). Results were mixed. The mineralized horizon was not reached due to problems penetrating the very resistant siliceous and brecciated rocks which overlie the upper Ogilvie Formation and cap the Katshat horizon. However, the presence of the siliceous rocks suggests that a strong stratabound mineralizing system existed well away from the surface exposures on Mike and Orma hills. The new information confirms that the Rusty Springs system is very large, and that it has significant potential remaining to be tested.

TIMING OF MINERALIZATION

The interpretation that Rusty Springs is a Mississippi Valley-type deposit related to karsting along the upper Ogilvie Formation contact suggests that the mineralizing event was likely bracketed by the Middle Devonian rocks below and the Late Devonian to Mississippian rocks above. On the other hand, the discordant nature of mineralization and alteration at Rusty Springs indicates that it postdates deposition of the early to Middle Devonian Ogilvie Formation and at least the lowermost part of the overlying Devono-Mississippian section. In addition, there is a lack of obvious cleavage development in the Ogilvie Formation dolostones, which contrasts sharply with most rocks across the property, including other carbonates. This suggests that the mineralizing event may even have postdated much of the Latest Cretaceous to Tertiary deformation affecting the area. Alternatively, it is possible that this may reflect a contrast in competency between the more competent silica-altered and dolomitized rocks associated with mineralization, and other less competent lithologies, or, that a more subtle stylolitic cleavage exists in the dolostones. Further study is needed. The parallelism of the Orma zone with structural trends (a fold axial plane?) and localization of Katshat-style mineralization in anticlinal hinge zones at Orma and Mike hills also supports the hypothesis that mineralization post-dated deformation. A relatively young age is also supported by the rare occurrence of discordant metre-scale quartz or Fe-carbonate vein/breccia bodies at high stratigraphic levels (Carboniferous to Permian) in the area surrounding Rusty Springs. Limited Pb isotope data supports the young age, as they approximate those of Cordilleran Ag vein deposits of Late Mesozoic age (Kirker, 1982).

GENESIS

As mentioned above, several deposit models, including those for MVT and hydrothermal replacement along a karsted surface, have been employed in an effort to aid exploration at Rusty Springs. Poor exposure and consequent lack of local bedding control has hindered the collection of evidence with which to evaluate the various models, as has leaching and oxidation of the mineralized zones and dolomitization of footwall rocks. However, discussion of some of the existing evidence is worthwhile so that some models may be critically evaluated and perhaps ruled out, and others put forward in the hope that they aid exploration.

MISSISSIPPI VALLEY-TYPE

Few, if any, of the textural features distinctive of MVT deposits (e.g., Leach and Sangster, 1993) have been positively identified on the property. For example, although the breccias common on the property have been interpreted as solution collapse features (e.g., Hansen, 1979; Hodder, 1997), cements and matrices of carbonate and local quartz are either massive or encrusted symmetrically around breccia fragments (e.g., Kirker, 1982). There is no evidence for infilling by internal sediment, which would be strongly suggestive of a karst environment. Stratigraphic evidence also appears to argue against a karst environment. No regolith is preserved along the contact between the Ogilvie Formation and the overlying siliciclastic rocks that would indicate subaerial exposure, and even evidence for uplift, such as the presence of coarse-grained clastic rocks, is lacking. According to Liedtke (1980), very little relief exists on the contact, and if anything, subsidence is indicated. The stratigraphic transition is from a shallow water environment in which platformal carbonate was deposited, to a deeper water environment in which basinal shales were deposited.

Differences from classic MVT deposits also exist in the geochemistry and mineralogy at Rusty Springs, as has been noted by many previous workers. The high copper and silver contents, as well as low Zn:Pb ratios are generally atypical of MVT deposits (Leach and Sangster, 1993), as are locally very high As and Sb values and the high Al values occurring in the Katshat unit (Termuende and Downie, 1997). A geochemical fingerprint such as this is more consistent with an epithermal origin for metals within the host unit. Similar arguments can be made on mineralogic grounds, with the siliceous character of alteration, particularly in the hanging wall, and the common presence of tetrahedrite and argentiferous galena, which are more diagnostic of vein rather than stratabound Ag-Pb-Zn deposits. Fluid inclusion and sulphur isotope data from quartz, calcite, and sphalerite at Rusty Springs are also more comparable to those from epithermal deposits than from those of MVT (Kirker, 1982).

Regionally, the evidence also argues against an MVT setting. As Hodder (1997) notes, it is significant that the Ogilvie Formation at Rusty Springs is comprised largely of dolostone in an area in which limestone generally predominates. Even within the Ogilvie Formation itself, the regional dolomitization common to MVT districts appears to be absent. Norris (1996) describes only local dolomite beds in the lower part of the Ogilvie Formation in measured sections farther south in the Ogilvie Mountains.

In spite of the arguments against the presence of MVT mineralization, it remains possible that the mineralization and alteration evident on the Rusty Springs property may simply be the distal expression of a more typical MVT system. However, it may be an MVT system with its origins in a hydrothermal karst system, rather than a meteoric or meteoric-hydrothermal one (*cf.* Leach and Sangster, 1993).

HIGH-TEMPERATURE, CARBONATE-HOSTED MASSIVE SULPHIDES: MANTO-CHIMNEY COMPLEXES

The mineralizing system at Rusty Springs bears some of the features of high-temperature, carbonate-hosted massive sulphide deposits (Titley, 1993), which are also commonly referred to as manto-chimney complexes, and are rich sources of base and precious metals. This type of deposit, although occurring in quite varied structural or stratigraphic settings, is typically wholly or partially stratabound, commonly contains abundant pyrite, and contains Pb and significant Ag. Copper and Au can be present but are less common than Ag-Pb-Zn, and enrichment in one or the other of Cu-Pb-Zn can be variable. The deposits are generally thought to occur by replacement processes, initiated by hot fluids and/or gases, above or near centres of thermal activity, and thus intrusions are commonly (though not always) spatially associated. Vein, skarn, and even porphyry copper deposits may be closely associated with the manto-chimney ores, and it is generally accepted that all are genetically related to the associated intrusions (Titley 1993).

Termuende (1996) initially recognized the potential for manto-chimney deposits at Rusty Springs. The few preserved hypogene ore minerals recognized at Rusty Springs, such as galena and tetrahedrite, are common in the manto-chimney class. The silica alteration common on the property is also commonly peripheral to ore in this deposit type, or at least to districts in which such deposits occur. In addition, dolomitization is known to play a role in the formation of many high-temperature, carbonate-hosted deposits, and breccia bodies also common to these systems (Titley, 1993). The apparent controls on mineralization at Rusty Springs, such as the overlying impermeable fine-grained siliceous shale cap, and perhaps the anticlinal fold hinges at Mike and Orma hills, also bear similarities to some manto-chimney deposits (e.g., Tombstone, Arizona; Titley, 1993). This factor of predictability is an important advantage in exploration for manto-chimney ores, since they are known to be difficult in terms of exploration. One of the main arguments against the application of the manto-chimney model at Rusty Springs is the lack of direct evidence for intrusive rocks, either on the property or in the region. However, Chernoff (1976) shows an inferred intrusion at depth below the domal core of the Rusty Springs antiform. The nearest known plutons to Rusty Springs property are Devonian (?) in age and outcrop to the north in the vicinity of Old Crow (Fig. 1; Woodsworth et al., 1991).

OTHER ECONOMIC POTENTIAL IN THE VICINITY OF RUSTY SPRINGS

Little in the way of significant mineralization has been found in the immediate area around Rusty Springs, but recent work and a re-evaluation of work done previously indicates that some potential exists and warrants testing. For example, in the most recent drilling, an interval approximately 40 m thick within the Devono-Mississippian pyritic shales that overlie the Ogilvie Formation was highly anomalous in zinc. It included intersections of 7 and 15 m, which returned nearly 3000 ppm Zn. Although the hole did not reach its target, it is estimated that the Zn-rich zone lies approximately 100-150 m up-section from the Ogilvie Formation, at about 250 m depth. The zone occurs within a siliceous or weakly silicified carbonaceous pyritic mudstone. Sphalerite occurs as disseminated fine- to medium-grained, honey-brown grains, both within mudstone clasts, and within host rocks, as well as in zones of quartz or quartz-carbonate microbreccia. The pyritic and locally zinc-rich shales may be the source for the gossanous springs near the base of the north end of Mike Hill which lend their name to the Rusty Springs property. In fact, sediment issuing from the springs themselves was highly anomalous in zinc (Chernoff, 1976). This suggests further that the recessive shale package may have potential for hosting Zn deposits, either similar in character to Rusty Springs, or perhaps of the Sedex type (sedimentary exhalative). Rocks of similar age, character, and tectonic setting further southward in the Cordillera (e.g., Macmillan Pass area, Yukon; Gataga district, B.C.; Dawson et al., 1991) also indicate similar mineral potential. One might begin to evaluate this potential immediately south-southeast of the area mapped, where rusty creeks and springs, similar in appearance to those at the Rusty Springs property, were noted in the drainage that lies in the recessive core of Norris' (1981) Porcupine Anticline. The springs likely emanate from rocks correlative with the recessive and pyritic Devono-Mississippian rocks that overlie the Ogilvie Formation in the area mapped.

With regard to other possibilities, rare iron-carbonate breccia and siliceous veins and vein breccias were noted in outcrop or float while mapping the surrounding ridges, but none bore visible sulphides, appeared extensive, or was accompanied by significant alteration. About 40 km further south, however, at the Pama (Bern) occurrence, which lies just inside the western boundary of the proposed Fishing Branch Protected area, an impressive, steeply dipping, north-northwest-trending quartz-carbonate breccia zone that is hosted by carbonates can be traced for greater than 2 km. It is outlined by a broad and intense soil geochemical anomaly (O'Donnell, 1974) and near its southern end, contains tetrahedrite, copper oxides, and zinc and lead sulphates that bear some similarities to mineralization at Rusty Springs. The Pama property has never been drill-tested, yet smithsonite-rich samples yield assays of up to 47.80% Zn. Although it is hosted in carbonates and has at least some mineralogic similarities to Rusty Springs, no convincing evidence was found at the Pama property that was suggestive of a significant element of stratigraphic control to mineralization. The breccia zone is hosted by limestone that is probably correlative with the uppermost limestones in the vicinity of Rusty Springs (Upper Carboniferous and Permian (?); considerably younger than the Ogilvie Formation). The breccia appears to dip steeply to the east-northeast, and lies subparallel to the steeply dipping eastern limb of what appears to be a gently southerly plunging, asymmetric, east-vergent antiform. The breccia appears to be hosted entirely within limestone, and the limestone is only very locally dolomitized, which is in sharp contrast to Rusty Springs, where the better part of the Ogilvie Formation is dolomitized. Overlying the limestone is a sequence of relatively recessive, fine-grained black carbonaceous rocks that appears to be capped by more resistant siliceous sandy beds. The sequence is similar in appearance to the Jurassic and Lower Cretaceous rocks along the east margin of the area mapped at Rusty Springs.

SUMMARY AND CONCLUSIONS

In spite of many years of sound exploration work, the genesis of the Rusty Springs prospect remains incompletely understood, yet its considerable potential for a large-tonnage Ag-Pb-Zn-Cu deposit remains inadequately tested. The extent of the mineralized and altered rocks at Rusty Springs suggests that the hydrothermal system is large. In fact, limits to the altered and brecciated zones in the upper Ogilvie Formation have yet to be established, with the possible exception of the northeast part of the property (Bankowski, 1980b). The size of the mineralizing system, together with its apparent stratabound nature, its commonly significant but sub-economic thicknesses, its local high grades, and its potential for supergene enrichment, indicates that Rusty Springs remains an attractive exploration target. Future exploration should be drill-oriented and should target the uppermost Ogilvie Formation beneath Devono-Mississippian fine-grained clastic rocks to the south and southeast of Mike and Orma hills.

The region surrounding Rusty Springs has the potential for Sedex-type mineralization displayed by the Devono-Mississippian fine-grained clastic rocks, and that of the carbonate-hosted vein/breccia on the Pama claims. This suggests that prior to alienation of the large tracts of land in the proposed Fishing Branch Protected Area that are underlain by favourable geology, the Paleozoic rocks (at a minimum) merit baseline geological information, such as regional stream sediment data controlled by up-to-date 1:50 000 scale geologic mapping. This information is particularly relevant in areas like the northern Yukon, which are more difficult to explore because of the lack of extensive Pleistocene glaciation. Such data collection can only provide a more sound footing for the present process of Protected Area evaluation and will yield a useful database for all stakeholders.

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APPENDIX 1

Summary of exploration work on the Rusty Springs property.

Year	Work done	Company	Interpretations	Drilling	Significant results	Expenditure	Reference
1976	staking, prospecting, mapping, limited soil sampling, hand-pitting	Rio Alto Exploration Ltd.	intrusive-related hydrothermal vein systems with supergene enrichment		Chip samples of float from several localities with 30-40% Zn, 5-15% Cu, and variable Pb and Ag; grab samples commonly averaged 10-70 opt (300-2000 g/t) Ag	$150,000	Chernoff (1976)
1977	prospecting, mapping, grid-soil sampling, diamond drilling, staking, metallurgical sampling	Rio Alto Exploration Ltd.	precious-metal-enriched Mississippi Valley-type (MVT) model adopted	3200 ft. (975 m) in 8 holes	High Ag and Pb values in one hole (123 ft. averaging 33.27 opt (947.5 g/t) Ag, 4.72% Pb, 2.36% Cu) but with poor recoveries	$187,000	White (1978); Schoel (1978)
1978	extensive line cutting and soil geochemistry, prospecting, diamond drilling, mapping, construction of winter road and airstrip	Rio Alto Exploration Ltd.	mineralized zones on Orma Hill follow low-angle fault; MVT model still accepted	6035 ft. (1840 m) in 30 holes	stratigraphic control noted on anomalous soil geochem zones following chert–dolomite contacts: Cu-Pb-Ag±Zn on Orma Hill; Zn±Cu±Pb±Ag on Mike Hill; poor recoveries in drilling	$555,000	Beck (1978)
1979	Induced Polarization and gravity surveys, line cutting, prospecting, mapping, soil sampling, hand pitting, trenching	Rio Alto Exploration Ltd.	MVT model still accepted		extent of upper Ogilvie Formation (mineralized showings or float found throughout) and contacts with overlying siliciclastic rocks established	$300,000	Hansen and Bankowski (1979); White (1979)
1980	diamond drilling, cat trenching, detailed mapping	E&B Explorations Inc. and Rio Alto Exploration Ltd. joint venture	mineralization considered to be of hydrothermal origin; Ogilvie-Hart River contact still considered a karsted horizon channelling mineralizing solutions	6,000 ft. (1829 m) in 27 holes	poor recoveries in upper parts of holes; numerous cm- to decimetre-thick tetrahedrite-tennantite veins intersected, which commonly yielded high Ag, Pb, and Cu values; mineralization on Orma Hill in part appears to be vein-related	$1,200,000	Bankowski (1980); Liedtke (1980)
1982	soil geochemistry, VLF-EM surveys, mapping, trenching, diamond drilling	Kenton Natural Resources Corporation	epithermal veins	1673 ft. (510 m) in 7 holes	common WNW-, NW-, and NNW-trending EM conductors outlined; Orma Hill vein systems defined	$116,000	Davis and Aussant (1982)
1983	fill-in soil geochemistry and VLF-EM surveys, diamond drilling	Kenton Natural Resources Corporation	epithermal veins	1600 ft. (488 m) in 2 holes	focussed on Orma Hill vein systems	$350,000	Aussant (1983)
1986	diamond drilling	Kenton Natural Resources Inc.		1326 ft. (404 m) in 2 holes	tested (unsuccessfully) IP anomalies between Orma and Mike hills	$96,000	Chamberlain (1986)
1992	restaking						

Appendix 1. *continued*

Year	Work done	Company	Interpretations	Drilling	Significant results	Expenditure	Reference
1994	regional reconnaissance; trenching, airstrip and road construction; clean-up	Eagle Plains Resources Ltd.	epithermal veins, MVT		vein mineralization on 040°-trend discovered using soil geochem and trenching on Mike Hill; new showings discovered SW of Mike Hill	$190,000	Downie (1994)
1995	trenching, diamond drilling, soil geochemistry, staking, airstrip and road construction, GPS survey, claim staking	Eagle Plains Resources Ltd.	manto-chimney-type carbonate-hosted deposits	5440 ft. (1658 m) in 21 holes	15.1 oz/ton (425 g/t) Ag, 3% Cu, and 1.3% Zn over 50 ft. (15.3 m) on Mike Hill	$539,000	Termuende (1996)
1996	diamond drilling; airstrip extension, road construction, staking	Eagle Plains Resources Ltd.	carbonate-hosted manto-type deposits; stratabound hydrothermal mineralization along Ogilvie-Hart River Formation contact	7610 ft (2320 m) in 15 holes	highly anomalous base metal values over significant widths along Ogilvie-Hart River Formation contact	$560,000	Termuende and Downie (1997)
1997	reverse-circulation drilling, surface mapping, prospecting, road and drill pad construction, improvements to airstrip	Eagle Plains Resources Ltd. and Canaustra Resources Ltd.	stratabound hydrothermal mineralization along Ogilvie-Hart River Formation contact	1351 feet (412 m) in 8 holes	two widely spaced holes drilled through Ogilvie-Hart River Formation contact, confirming presence of stratabound mineralization; affirmation of distribution of chert and shale, including in low-lying areas (may cap mineralization preserved beneath the water table)	$356,000	Termuende and Downie (1998); Hodder (1997)
1998	gravity and seismic reflection surveys, property reconnaissance prospecting and mapping	Eagle Plains Resources Ltd. and Canaustra Resources Ltd.	stratabound hydrothermal mineralization along Ogilvie-Hart River Formation contact, below present and paleo-water tables		continuation of prospective stratigraphy at shallow depths northeast of Orma Hill; coincident with gravity anomalies	$54,000	Power (1998)
1999	diamond drilling, property-scale mapping, regional reconnaissance mapping, prospecting, and sampling; clean-up	Eagle Plains Resources Ltd. and Canaustra Resources Ltd.	stratabound hydrothermal mineralization along Ogilvie-Hart River Formation contact, below present and paleo-water tables	1040 ft. (317 m) in 3 holes		$273,000	in progress
				total drill frontage: 36,264 ft. (11,050 m) in 123 holes		**total expenditures: $4,927,000**	

APPENDIX 2

Exploration methods employed on the Rusty Springs property.

Method	Aim of survey/application	Results and comments	Recommendations
prospecting	locating mineralization	successful in locating silica-hosted vein-type mineralization	useful for following-up geochem
soil geochemistry	to locate potential mineralized zones and target trenches and drill holes	in spite of thick overburden and permafrost, effective in outlining near-surface mineralization	target top of Ogilvie Formation on remaining unsampled parts of property
stream geochemistry	location of new drill targets	creek sampling led to discovery of new showings local to property; geochemically anomalous drainages present in region	regional stream sediment sampling, targeting Ogilvie Formation and overlying shale
trenching	to reach bedrock	mixed success with cat trenching: bedrock exposure not guaranteed; may require 2 seasons; environmental degradation problems	any further trenching may be more successful using an excavator
geophysics	targeting drill holes	most geophysical anomalies tested were coincident anomalies	
IP	targeting sulphides	resistivity anomalies outlined, but drill testing unsuccessful	not recommended without sound geologic framework
VLF-EM	targeting conductive sulphide horizons	many conductors outlined, but drill testing unsuccessful; may outline water-filled gougy fault zones	not recommended without sound geologic framework
magnetometer	targeting sulphides	anomalies outlined but unexplained; drill testing unsuccessful	not recommended without sound geologic framework
gravity	targeting more dense sulphides	anomalies outlined, but drill testing unsuccessful	several anomalies untested; not recommended without sound geologic framework
seismic	determining depth to favourable stratigraphic contact	unsuccessful, possibly imaged permafrost horizon	not recommended without sound geologic framework
drilling			
diamond drilling		reasonable drilling and recovery in oxidized mineralized zones using modern equipment and drilling techniques; drilling slow in resistant siliceous zones	recommended for future work; need high-powered rig, plenty of casing, mud, bits, core barrels, and patience
RC drilling		difficult drilling in oxidized mineralized zones; good drilling in resistant siliceous zones	not recommended