

# Geology, alteration, and mineralization of the Carlin-type Conrad zone, Yukon

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## ABSTRACT

The Conrad zone, east-central Yukon is a newly discovered gold prospect. It is strongly analogous to Carlin-type mineralization, and represents the first Carlin-type gold deposit discovered in Yukon. The regional geological framework and style of mineralization bear similarities to the Carlin trend in Nevada. Structurally, the Conrad area is bounded to the south by the regional-scale Dawson thrust and the Kathleen Lakes fault to the north. This structural setting lies at the interface between the dominantly clastic Neoproterozoic to Paleozoic rocks of Selwyn basin and coeval carbonate rocks of Mackenzie platform. The principal host rock to mineralization is a variably decarbonatized silty limestone, although where permeability has been enhanced by shearing, siliciclastic rocks may also contain significant amounts of gold. Alteration and associated processes related to mineralization include decarbonatization of host limestone with subsequent silicification and brecciation. Gold is hosted within arsenic-rich pyrite growth rims around pre-existing pyrite. Significant post-mineralization realgar, orpiment, calcite, and trace stibnite are found locally as open-space minerals.

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## INTRODUCTION

The Conrad zone (Fig. 1) is a new Carlin-type gold discovery in Yukon. The Nadaleen trend, which hosts the Conrad zone, lies in the eastern part of ATAC Resources Limited's Rackla Gold Property (Fig. 2). The Conrad zone drilled prospect is located in east-central Yukon, 185 km northeast of the town of Mayo (Fig. 1). Significant Carlin-type mineralization discovered thus far at Conrad includes diamond drill intersections of 42.9 m of 18.44 g/t Au (ATAC Resources Ltd., 2012a). The discovery of a Carlin-type deposit in Yukon has wide ranging implications for the area given the immense size and clustered nature of Carlin deposits as recognized in Nevada.

Carlin deposits are characterized by sediment-hosted micron-scale gold within disseminated arsenian pyrite (Arehart, 1996). Deposits are typically found as replacement deposits in silty-carbonate, and have

both structural and stratigraphic controls with strong relationships to deep seated crustal-scale structures (Cline *et al.*, 2005; Muntean *et al.*, 2011). Carlin fluids are typically weakly acidic, which results in the dissolution of carbonate. This is followed by precipitation of quartz and gold-bearing arsenian pyrite as well as trace metal enrichments of As-Tl-Hg-Sb-(Te) (Muntean *et al.*, 2011). At the Conrad zone, mineralization occurs within slope and basinal facies carbonate and clastic rocks. Mineralization is found associated with disseminated sulphides and is classified as carbonate replacement, associated with silicification and brecciation. The Conrad zone is strongly analogous to Carlin-type mineralization, and does not resemble nearby intrusion related deposits of the Tombstone suite as described by Stephens *et al.* (2004) or the recently discovered intrusion-related carbonate replacement Tiger zone (100 km to the west) as described by Theissen *et al.* (2011).

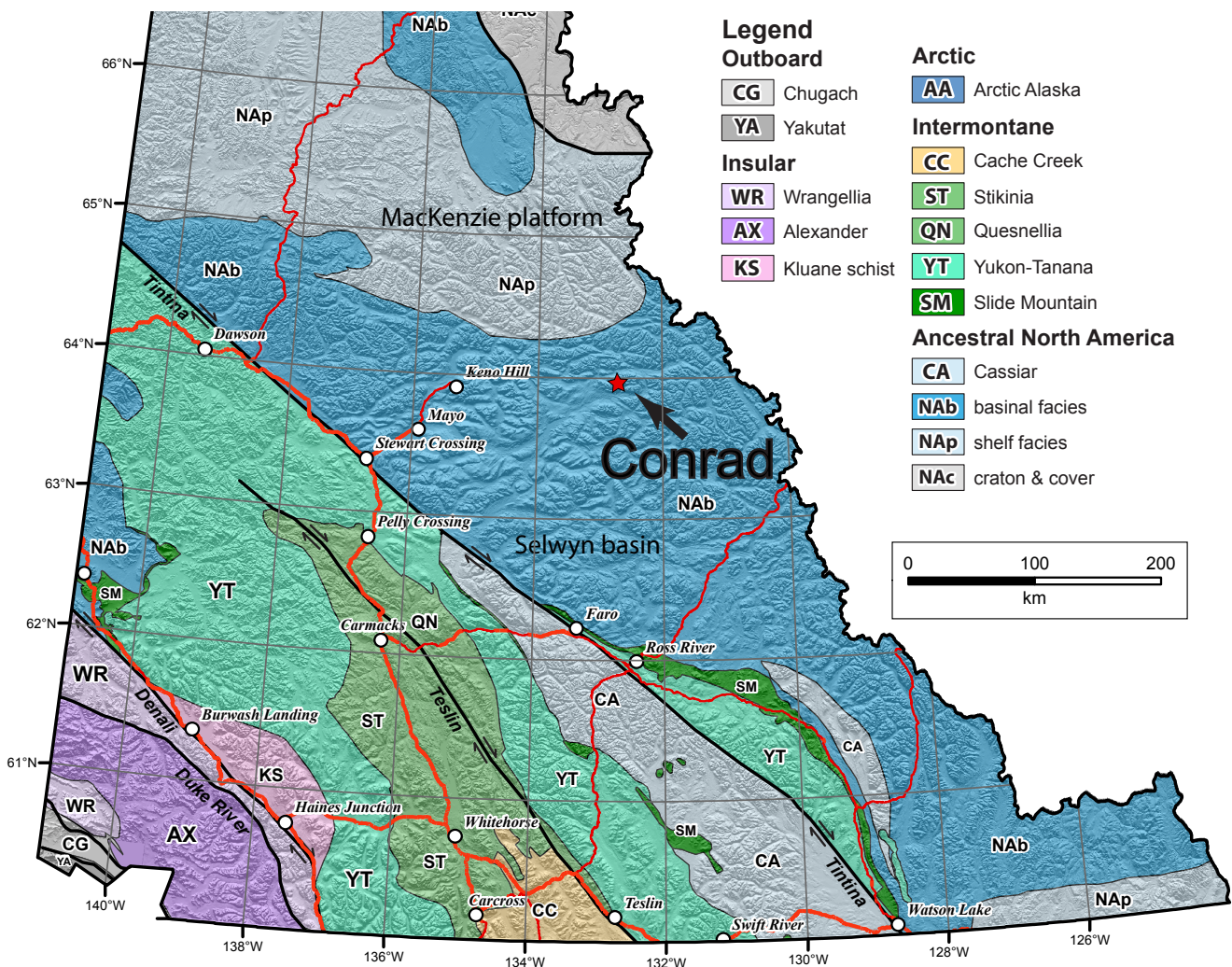
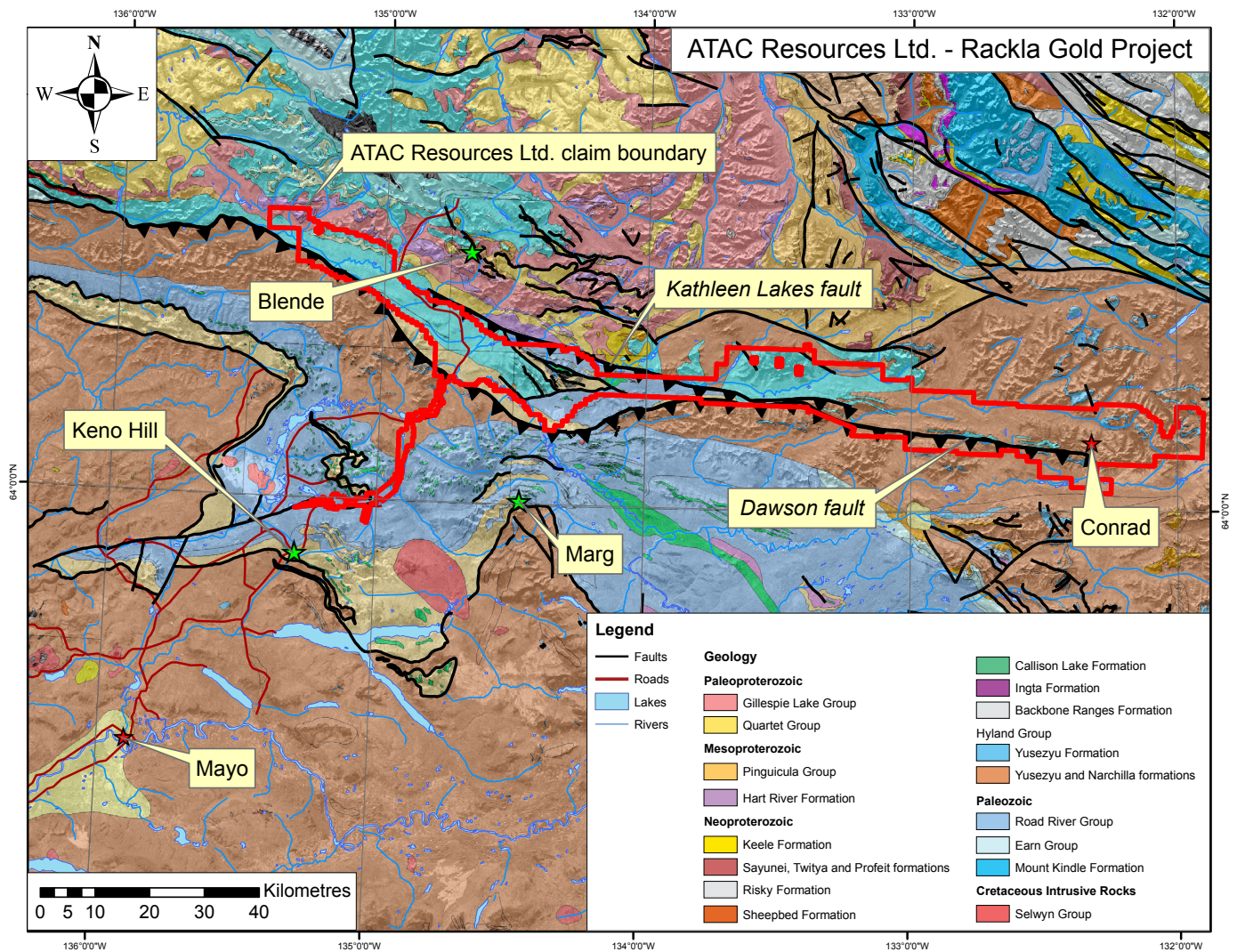


Figure 1. Terrane map of Yukon showing the location of the Conrad zone in the northern Selwyn basin.



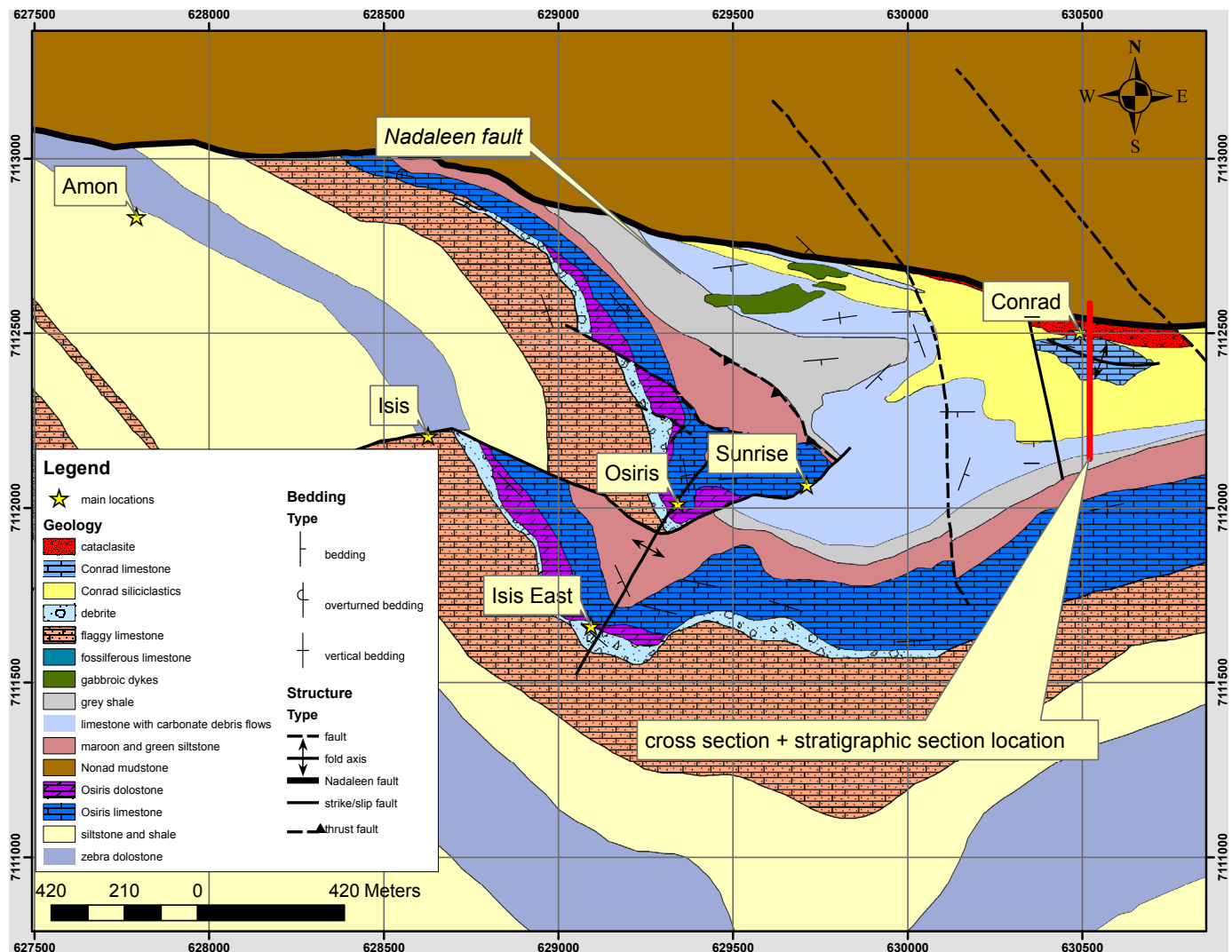
**Figure 2.** Regional geology of the Rackla Gold Project (red outline). Major faults are indicated as well as some significant mineral occurrences in the region (as green stars).

This study is part of an MSc project that will characterize the geology, alteration, and mineralization of the Conrad zone in order to develop a deposit and exploration model. This paper presents detailed characterization of lithologies, mineralization, and observed timing relationships. A preliminary paragenesis is presented based upon field observation of outcrops and detailed core-logging. Additionally, petrographic and Scanning Electron Microscope (SEM) analysis of the major rock types and the various stages of mineralization were utilized to constrain the paragenetic sequence presented here.

#### EXPLORATION HISTORY

The Nadaleen Trend was discovered in the summer of 2010 by ATAC Resources Ltd. during follow-up of

arsenic anomalies in stream sediment. This resulted in the discovery of multiple mineralized zones with the season culminating in drilled intersections of mineralization at the Orisis, Conrad, and Isis zones within the Nadaleen trend (Fig. 3). During 2011, exploration and drilling of the area resulted in the expansion of the Conrad and Osiris zones and the discovery of the Amon and Isis East zones. Drilling projects in 2012 further expanded known mineralized zones, and led to the discovery of the Sunrise zone (ATAC Resources Ltd., 2012b). Follow up from prospecting in 2011 and subsequent drilling in 2012 discovered the Anubis prospect, located 10 km west of the Osiris and Conrad zones (ATAC Resources Ltd., 2012c).



**Figure 3.** Local geology of the Nadaleen trend. Major faults are indicated along with other mineral occurrences on the property. The location of the stratigraphic section shown in Figure 4 is indicated by red line.

## REGIONAL GEOLOGY

The Nadaleen trend lies at the interface between the Neoproterozoic to Paleozoic rocks of the Selwyn basin and MacKenzie platform (Fig. 2). Rocks of Selwyn basin in the area are dominated by slope and basin facies carbonate, clastic rocks, and siltstone with significant deep water black shale and chert, whereas the Mackenzie platform is dominated by shallow water platformal carbonate (Abbott *et al.*, 1986). The area is bound structurally to the south by the Dawson thrust and to the north by the Kathleen Lakes fault. The Dawson thrust is believed to be a reactivated Neoproterozoic normal fault that lies at the northernmost boundary of the Selwyn basin and is marked by an abrupt facies change to the

Mackenzie platform (Mair *et al.*, 2006). Structures in Selwyn basin are dominated by a fold and thrust belt associated with north directed Mesozoic convergence (Mair *et al.*, 2006). The Nadaleen trend and its association with the Dawson thrust and the Kathleen Lakes fault may be analogous to the Roberts Mountain thrust in the Carlin trend where the majority of giant deposits lie within 100 km of the thrust (Cline *et al.*, 2005).

No intrusive units have been documented thus far in the vicinity of the mineralization, with the exception of small mafic dykes (described below). Two regionally developed intrusive suites are found in the area surrounding the Nadaleen trend. The Mayo suite to the south of the Nadaleen trend consists of felsic to mafic, sub-alkalic

intrusions dated between 96-90 Ma. This suite is part of the larger Tombstone suite associated with post-collisional extension in the Selwyn basin (Hart *et al.*, 2004). The small granitic Rackla pluton lies 100 km to the west; it has associated aplite dykes and pegmatites that have yielded  $^{40}\text{Ar}/^{39}\text{Ar}$  muscovite ages of  $62.3 \pm 0.7$  Ma,  $62.4 \pm 1.8$  Ma, and  $59.1 \pm 2.0$  Ma (Kingston *et al.*, 2009). A U-Pb date of  $62.9 \pm 0.5$  Ma for the Rackla pluton was also reported by Theissen *et al.* (2011). Although these two intrusive packages exist throughout Selwyn basin, a Cretaceous granodiorite pluton of the Mayo suite ~50 km to the southwest is the intrusion identified closest to the Nadaleen trend.

### PROPERTY GEOLOGY

The Nadaleen trend consists of a southward-younging sequence of sedimentary rocks that is in faulted contact

with a large mudstone package to the north (Fig. 3). Two different sedimentary packages can be separated in the strata to the south of the Nadaleen fault; Conrad and Osiris. The thick package to the north of the Nadaleen fault is an argillaceous mudstone to siltstone with isolated debris flow lenses. The Conrad strata, which underlies the Osiris strata consists of silty limestone with siltstone and sandstone as well as large carbonate debris flows inter-bedded with black shale/siltstone (Fig. 4). The Osiris strata consist of maroon and green siltstone underlying a main limestone package. A sequence of silty limestone and siltstone, diamictite, and dolomite overlie the main limestone unit. Small, east-west trending, mafic dykes have been identified trending parallel to the Nadaleen fault. The overall stratigraphy of the area remains unclear as little regional mapping has been carried out in the area. Ongoing mapping by the Yukon Geological Survey (YGS) is designed to improve the understanding of the regional stratigraphy.

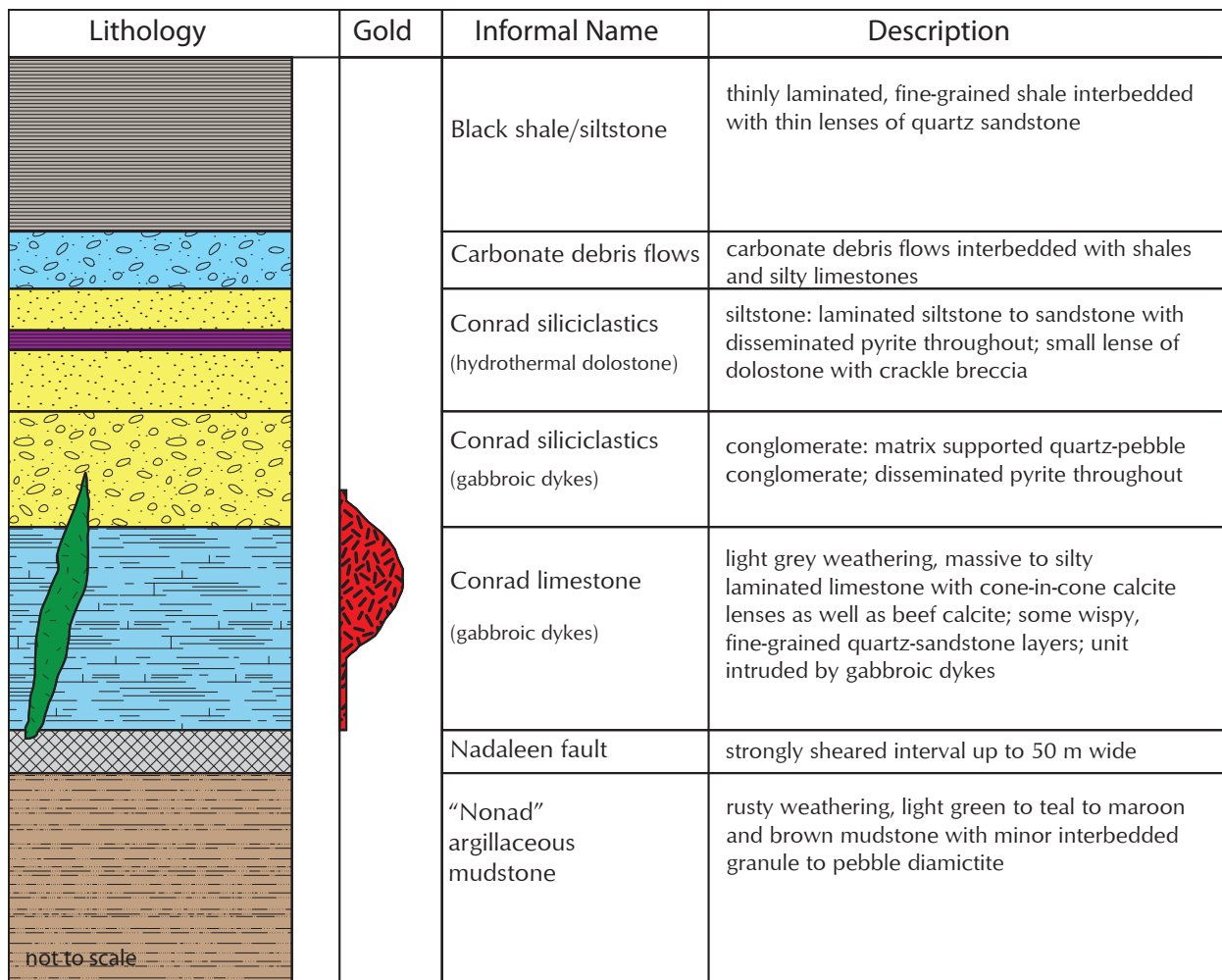


Figure 4. Simplified stratigraphic section of the Conrad zone. The sequence youngs to the south.

The Nadaleen trend has a complicated structural history, having been affected by several generations of faults and folds. The most prominent structural feature in the trend is the Nadaleen fault which separates the Conrad and Osiris strata from the argillaceous mudstone package to the north (Fig.5). The Osiris strata define two large scale antiforms that plunge steeply to the southwest. These two antiforms are separated by an east-west trending dextral strike-slip fault. The Conrad strata, on the other hand, are complexly folded. The Conrad limestone lies at the core of a doubly plunging antiform trending north-northeast. Evidence for other larger scale folds in the Conrad strata is not easily recognized, though small-scale chevron folds are observed within all siltstone and shale packages. The

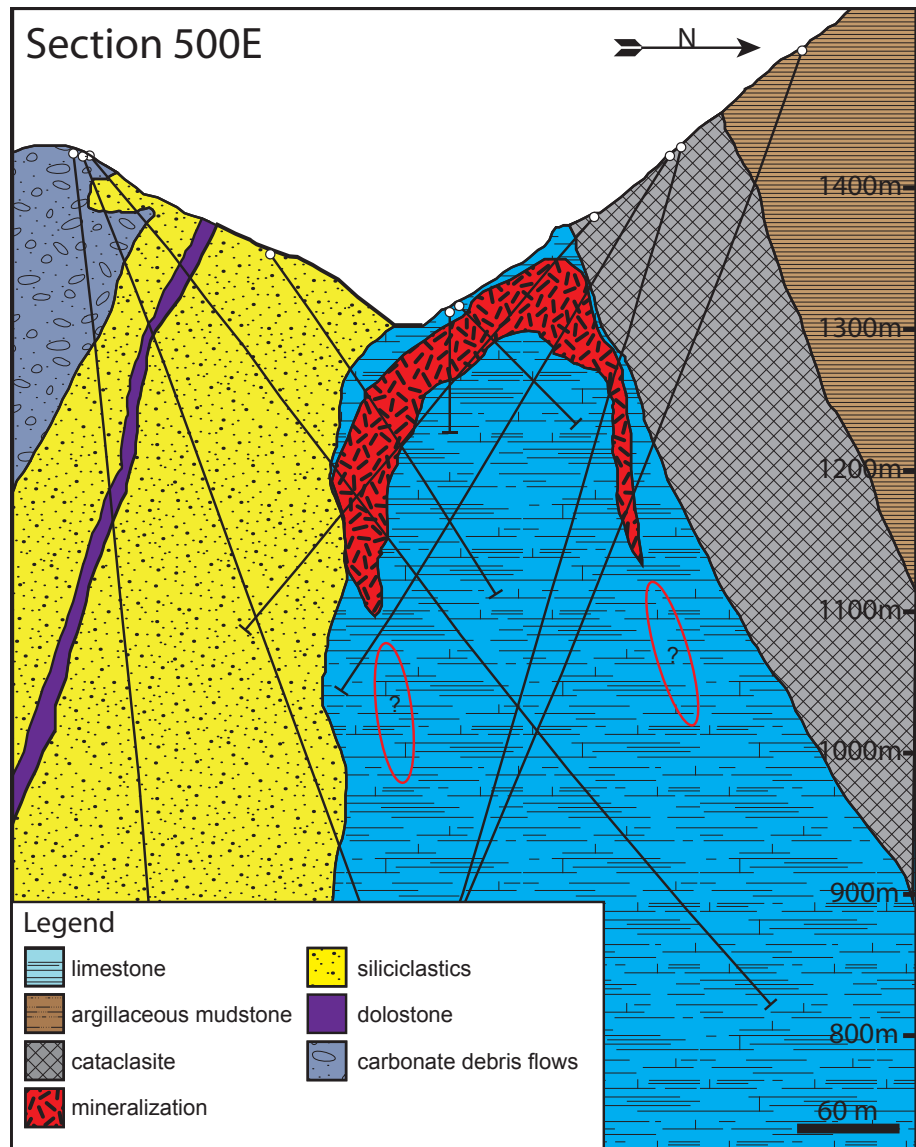
area is also cut by late, steeply dipping, northwest-trending faults that off-set mineralization locally. North-northwest bounding structures through valleys exist on the eastern and western extents of the area, separating the Conrad and Osiris strata from different sequences.

Numerous gold showings have been identified within the Nadaleen trend. An area approximately 4 by 2.5 km contains the mineralized zones known as Conrad, Osiris, Isis, Isis East, Amon, and Sunrise (Fig. 3). These zones occur within various carbonate packages across the trend, commonly containing realgar and orpiment with local decalcification and silicification. The Amon zone is hosted in dolomite and contains significant arsenic sulphides, but with minimal gold mineralization. The abundance and clustered nature of these showings and deposits signifies the metallogenic potential of the Nadaleen trend.

**GENERAL LITHOLOGIES**

**ARGILLACEOUS MUDSTONE - NONAD**

The argillaceous mudstone known colloquially as “Nonad” is a thick sequence that underlies the northernmost part of the property and extends beyond currently mapped units to the east, west, and north. The unit is separated from Conrad and Osiris strata by the east-trending Nadaleen fault. The unit is a moderately to readily weathering sequence, producing fine talus on slopes yet remaining resistant on ridges. The unit has a distinctive tan to rusty-brown weathering colour. Fresh surfaces are dominantly grey-green though can be maroon locally. Lithologies consist of very thinly bedded mudstone to siltstone with minor sandy beds (<1 cm) (Fig. 6a). Locally, there are lenses of diamictite with rounded sedimentary granules to pebbles in a sandy, calcareous matrix. Grains are dominantly angular to subrounded sub-millimetric quartz in layers alternating with silt and mud (Fig. 6b). The unit contains trace (<1%) amounts of pyrite disseminated



**Figure 5.** Simplified cross section through line indicated on Figure 3. Typical rock types are indicated with mineralization in an antiformal structure.

throughout silty beds. Distinctly maroon coloured layers can contain up to 5% disseminated hematite with rare chalcopyrite. The unit has been subjected to minor faulting throughout with well-developed cleavage locally. Thin, (3-15 mm) en-echelon calcite and dolomite veinlets are abundant throughout the unit; these veins tend to weather recessively. The Nonad mudstone contrasts starkly with all units to the south of the Nadaleen fault; the superposition of this package with sedimentary sequences to the south is a defining characteristic of the Nadaleen trend.

### CONRAD LIMESTONE

The Conrad limestone is a small, lenticular package with limited erosional exposure within an area of 300 by 70 m. It lies in faulted contact with the Nadaleen fault to the north and is in gradational contact on all other sides with the overlying siliciclastic package. The unit resists weathering and has a light grey weathering color. In hand specimen and in core, it is fine to medium grained, dark grey and crystalline (Fig. 6c). Thin bedding in the unit is visible in both hand specimen and core. Quartz and silt-rich interbeds up to 3 m thick are observed locally, typically close to contacts with above lying siliciclastic rocks. Areas of higher silt content within the limestone can have bedding parallel features such as “beef calcite” and “cone in cone calcite”. These features are found locally and range up to 4 cm in thickness. The limestone is dominantly calcite (60-95%), with silt and detrital quartz content varying from 5-30%, increasing towards the contact with the siliciclastic package.

Three generations of stylolites are present within the Conrad limestone. First generation stylolites are parallel to bedding and the most abundant. Second generation stylolites crosscut earlier bedding parallel stylolites, typically perpendicular to bedding planes. Third generation stylolites occur at many angles to bedding and crosscut all earlier phases along with early calcite veins. These stylolites have small enrichments of residual quartz grains as well as framboidal pyrite (Fig. 6d). Calcite surrounding the stylolites is typically recrystallized. As many as four generations of calcite veins and veinlets are present throughout the unit with the most dominant set being a conjugate set of veins with widths from 1 to 20 mm at high angles to bedding. Small and large scale chevron and open folds are present throughout the unit.

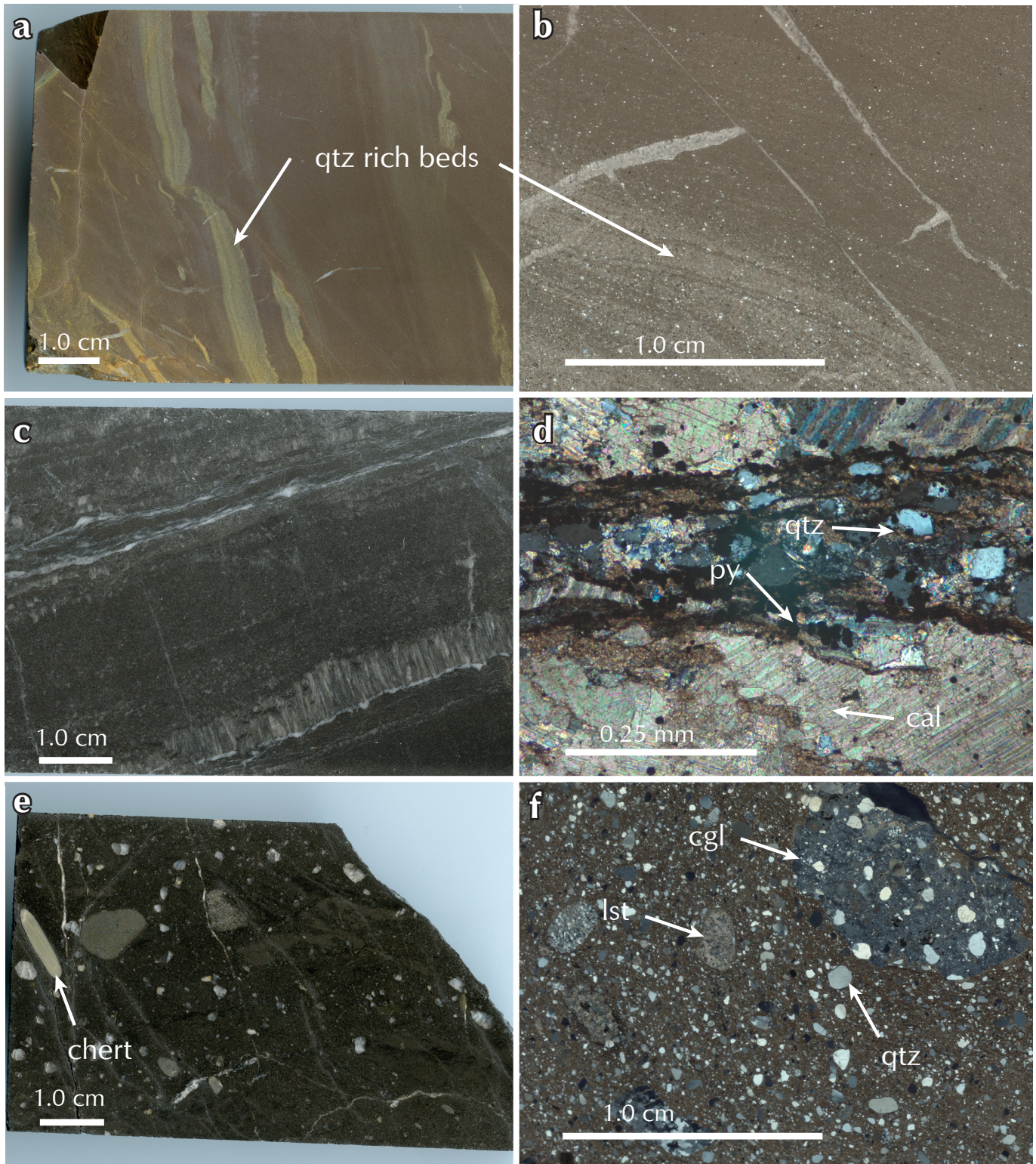
### SILICICLASTIC PACKAGE

The siliciclastic package has a large areal extent with limited outcrop. The unit has a northeast elongation

of approximately 1.5 km with the narrowest, northeast dimension being only 800 m within the mapped extent. The package is folded into an east and west-plunging antiformal dome with the Conrad limestone package at its core. Contacts with the limestone are all gradational. To the north, the unit is in faulted contact with the argillaceous mudstone across the Nadaleen fault. All southern portions of the unit are in gradational contact with an overlying carbonate debris flow unit. The package is very rusty brown in outcrop and typically weathers recessively. Fresh surfaces are dark grey to black. The unit is a siltstone to sandstone with lenses and interbeds of matrix and clast supported quartz-granule to pebble conglomerate (Figs. 6e,f and 7a). Siltstone to sandstone portions of this unit show regular bedding at 0.5-1 cm. Conglomerate lenses are typically matrix supported, though isolated zones of clast supported conglomerate are observed. Clasts are granule sized with some lenses of pebble conglomerates. Clasts are subrounded to rounded frosted quartz, chert, carbonate, and siltstone; whereas the matrix is dominantly silt and trace carbonate (Fig. 6b). Siltstone portions are dominated by quartz (85-95%). Typically, the quartz grains are small (<0.5 mm) and subrounded. Subrounded quartz grains dominate the coarser grained portions of beds (80-95%) with the remainder being dominated by silt (Fig. 7b). Pyrite is disseminated throughout both siltstone and conglomerate portions of the unit (2-6%) but localized layers of massive (>60%) pyrite have been observed. Sparse dolomite and calcite veinlets (<1 cm) are observed throughout the unit.

### CARBONATE DEBRIS FLOWS

The carbonate debris flow package is an irregularly shaped unit in gradational contact with the underlying siliciclastic package to the north. It is a resistive weathering sequence that is tan to buff colour on weathered surfaces. Fresh surfaces vary from dark grey to beige with a dark brown matrix. The unit consists of a series of megaclastic carbonate debris flows interbedded with black shale and limestone. The debris flows are large lenses of clastic material with blocks of carbonate as big as 2 m in diameter. These lenses typically occur at the base of the unit, transitioning to bedded limestone interbedded with black siltstone upwards in section. Debris flow lenses persist upward in section though thickness reduces considerably. Limestone towards the top of the section is thinly bedded with abundant bedding parallel “beef” calcite features. Ooids and cortoids are found locally throughout the matrix of the debris flows in between large carbonate fragments (Fig 7c). Clasts are primarily angular



**Figure 6.** Typical Conrad lithologies: (a) photograph sample of argillaceous mudstone; (b) photomicrograph illustrating bedding textures; (c) photograph of limestone (lst) illustrating bedding textures; (d) photomicrograph of stylolite in limestone (cal=calcite) illustrating pyrite (py) and quartz (qtz) within seam; (e) photograph of siliciclastic conglomerate (cgl) illustrating clast size and variety; and (f) photomicrograph of siliciclastic conglomerate illustrating varied fragment compositions and silty matrix.



fragments of dolostone, limestone, and siltstone-mudstone with angular to rounded quartz grains (Fig. 7c). Lithic fragments are large, ranging from centimetre to metre scale. Quartz grains dominate the smaller sized clasts present (2-10 mm). Matrix is dominantly silt-mud with trace carbonate (Fig. 7d). Matrix content varies from 15-50%. The unit has small sets of thin (<1 cm) calcite veinlets cutting throughout. The carbonate debris flow package is a unique and identifiable unit, and is an important marker horizon where present.

#### *BLACK SILTSTONE/SHALE*

The black siltstone/shale unit lies stratigraphically above the carbonate debris flow package forming a thin, wispy border at the top of the section. The unit is interbedded with the underlying package. The unit weathers recessively and is rarely observed in outcrop. Where visible, it is black with some minor rust staining, and is commonly only observed as small chips. On fresh surfaces, the unit is light grey to black in color. Thin laminations are present throughout (Fig. 7e). The unit is dominated by silt to mud with small contributions of 1-2 mm subrounded quartz grains locally (Fig. 7f). Trace disseminated pyrite is observed within quartz-rich beds. The unit is highly cleaved and also shows well-developed local chevron folding. Fracture surfaces are often conchoidal in nature. This unit has complex internal structures such as cleavage and folds, making it an important package for identifying key structures.

#### *DOLOSTONE*

A horizon of hydrothermal dolostone occurs within the siliciclastic package that underlies the carbonate debris flow unit. This is a very thin band parallel to stratigraphy that only outcrops in two locations within the Conrad strata. Where observed, it is resistive weathering with a dull, buff-grey colour. In hand specimen it is beige-grey and finely crystalline. Thin bedding is present locally. The unit is primarily composed of 80-90% sub-millimetre intergrown dolomite crystals (Fig. 7h). Pyrite is abundant throughout the unit, both disseminated and in veinlets (5-10%), trace (<1%) sphalerite is also observed. Distinct black crackle breccia veinlets (Fig. 7g) are found throughout consisting of sparry black-dolomite (20-50%) and quartz (50-80%) with minor pyrite. Although the dolostone appears to be hydrothermal in nature, it distinctly follows a specific horizon that is traceable in drill core as well as on surface. This unit appears to represent an early hydrothermal event associated with minor zinc mineralization.

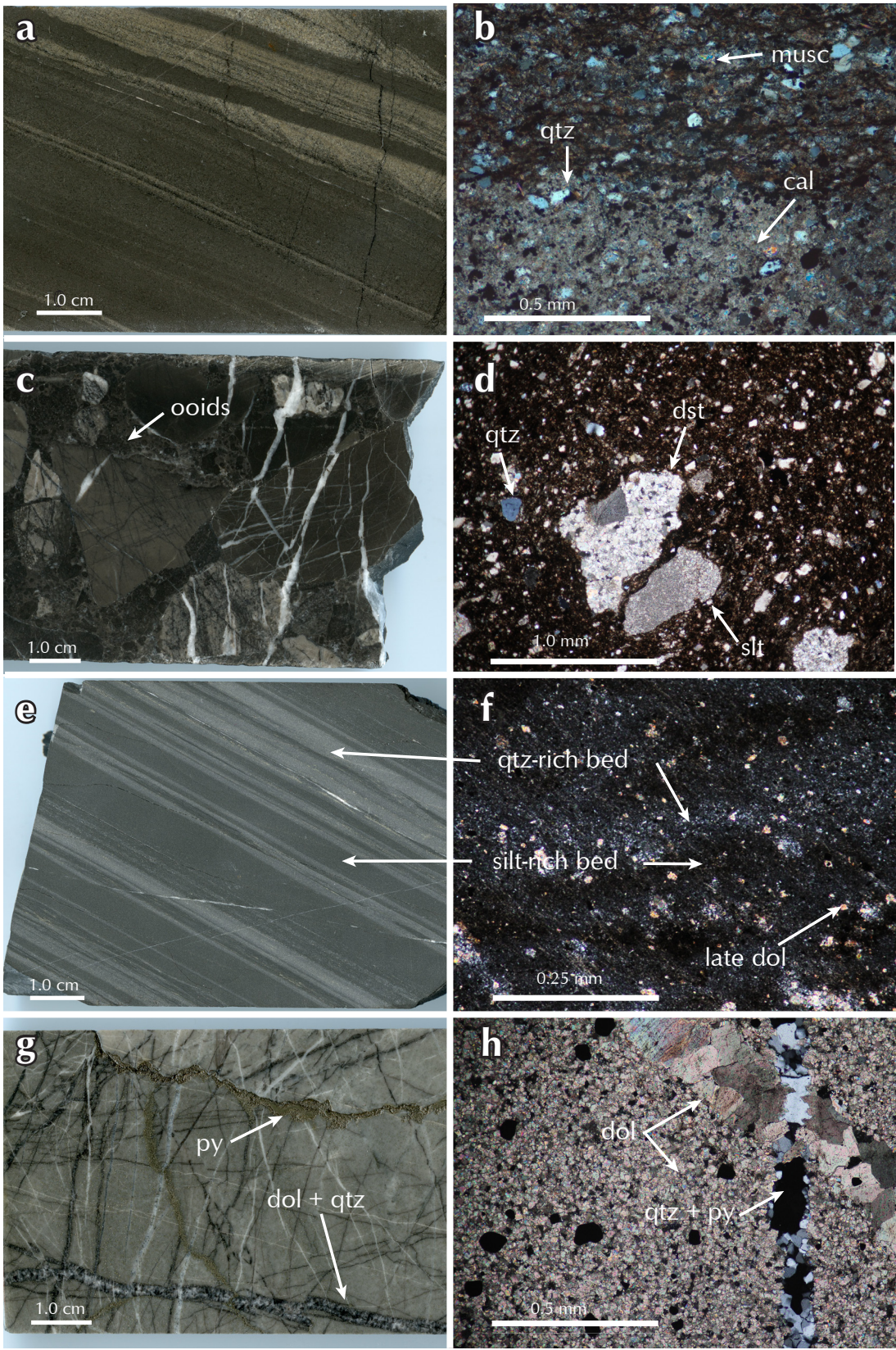
#### *NADALEEN FAULT CATACLASITE*

The Nadaleen fault is a distinctive feature of the Nadaleen trend. It is a steeply north dipping, east-trending structure that separates two distinct lithologic packages. It presents in drill core as a complex zone of cataclasite. This cataclastic zone can be up to 50 m in thickness and is only found directly adjacent to the fault (Fig. 5). In outcrop, it is a recessively weathering unit that is rusty brown in color. In hand specimen and in core, the unit ranges from light to dark grey. The zone contains deformed fragments of all of the rock types found in proximity to the fault. Fragments are highly variable in size with abundant, small 1-5 cm fragments as well as occasional fragments larger than 2 m. Composition of fragments is highly variable although abundance of fragment types corresponds to the nearest, non-deformed lithology. A fabric defined by rotated and elongated clasts and fine silt is well developed locally (Fig. 8a). The fine-grained silty groundmass is composed primarily of muscovite, much of which defines shear fabrics (Fig. 8b). Up to 5% disseminated and blebby pyrite is found within the cataclasite (Fig. 8b). The kinematics of this fault are inconsistent, as both sinistral and dextral indicators are observed, indicating multiple generations of movement. The complexity of the cataclasite and enigmatic nature of the movement along the fault zone may indicate that the Nadaleen fault was a long lived structure, subject to multiple generations of movement.

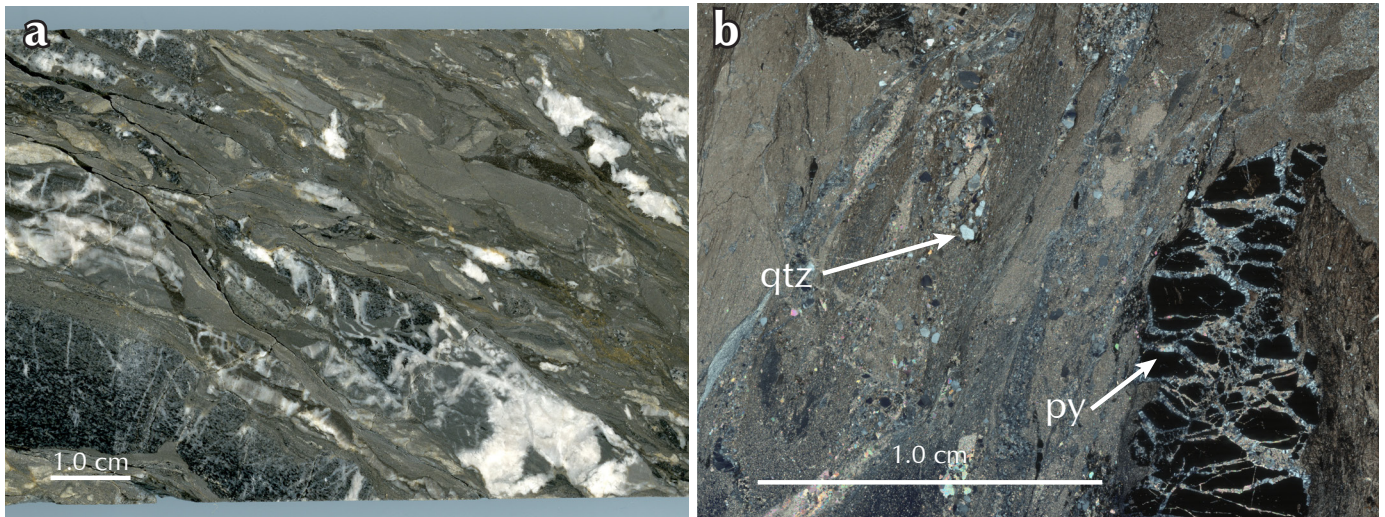
#### *MAFIC INTRUSIVE ROCKS*

A series of mafic dykes have been identified in the Nadaleen trend. These are found within an area where no intrusive rocks have previously been observed. The dykes are steeply dipping, east-trending and sub-parallel to the Nadaleen fault, ranging in thickness from 25 cm to 25 m. The majority of dykes found thus far have been drill core intersections as very few outcrops of the unit are present. Within the Conrad zone the dykes crosscut the limestone and siliciclastic packages. One particular dyke parallels the lower contact of the Nadaleen fault zone. Locally, fragments of this dyke are incorporated into the cataclasite. Where intersected in drill core, the dykes contain abundant xenoliths of proximal country rocks. The dykes intrude along fault zones; their proximal nature to the Nadaleen fault as well as incorporation into the cataclasite locally indicating that there is some movement along the fault post dyke emplacement.

The mafic dykes are greyish green with a slight rusty coating on weathered surfaces. Fresh surfaces are



**Figure 7.** Typical Conrad lithologies: (a) photograph of pyrite rich siltstone; (b) photomicrograph of siltstone illustrating abundant quartz and variable bedding (musc = muscovite); (c) photograph of carbonate debris flow package with ooids and cortoids in matrix; (d) photomicrograph of carbonate debris flow unit illustrating high silt content in matrix and varied clast compositions (dst = dolostone, slt = siltstone); (e) photograph of black shale unit with quartz-rich beds; (f) photomicrograph of black shale package showing thin beds and late stage dolomite (dol); (g) photograph of hydrothermal dolostone illustrating crackle breccia texture and abundant pyrite; and (h) photomicrograph of dolostone showing fine grained dolomite with abundant pyrite.



**Figure 8.** Nadaleen fault cataclasite zone lithologies and textures: (a) photograph of cataclasite illustrating well-developed shear textures; and (b) photomicrograph illustrating shear textures and pyrite content.

dark grey and coarsely crystalline (Fig. 9a). Chilled margins are common along dyke margins. The dykes are gabbroic in composition, dominated by amphibole (30-45%) and plagioclase (25-40%) with minor clinopyroxene (10-15%), trace pyrite is observed disseminated throughout (Fig. 9b). Texturally, large euhedral amphibole crystals enclose interstitial plagioclase with laths of some minor plagioclase (0.5-2mm). One dyke identified has similar composition but is very distinct texturally. Carbonate amygdules are abundant (10-25%), as well as lesser (<10%) plagioclase phenocrysts up to 8 mm (Fig. 9c). These phenocrysts occur within a very fine grained groundmass dominated by very fine-grained amphibole and plagioclase with trace pyrite (Fig. 9d).

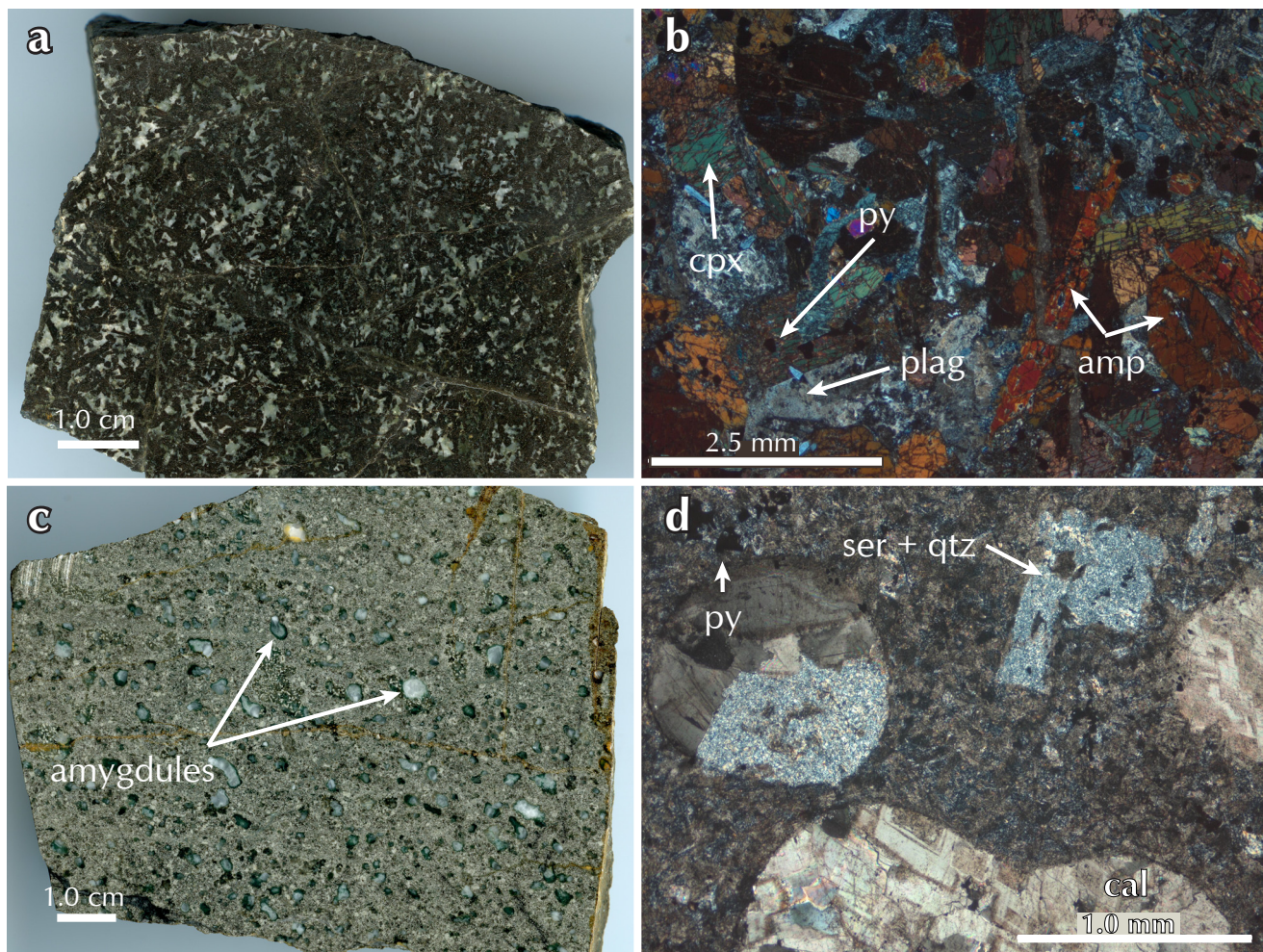
The gabbroic dykes show little evidence of deformation. No discernible fabric or folding has been identified but there are small fractures and very minor faulting present throughout. All dykes are altered to some extent. Least altered rocks are distinctly green and show amphibole replacement by chlorite. Plagioclase typically shows patchy sericite alteration. Secondary pyrite is also present; disseminated throughout sites previously occupied by mafic minerals. The most highly altered dykes are proximal mineralization and are characterized by strong, pervasive sericite alteration. Mafic minerals have been replaced by carbonate, pyrite, and sericite. Porphyritic and amygdaloidal dykes exhibit sericitic alteration of plagioclase phenocrysts and carbonate, sericite, and pyrite alteration of mafic groundmass. Small calcite and quartz veinlets are rarely observed. The mafic dykes are

also locally mineralized with abundant pyrite and trace realgar. The gabbroic dykes pre-date mineralization, possibly preserving a record of alteration induced by the mineralizing fluid.

## ALTERATION AND MINERALIZATION

The primary style of alteration associated with mineralization is decarbonatization of host limestone (Fig. 10a). Large amounts of carbonate are removed from the host limestone creating large amounts of insoluble residue, consisting primarily of detrital materials from within the host carbonate. In hand specimen, this is manifested as a very fine grained, sooty, black material, which is commonly found within early stylolites. Stylolites observed near areas of mineralization are thick (0.5-1.5 cm) and are powdery and unconsolidated. The majority of this material (>80%) is very fine grained brown to black residue with 5-10% detrital quartz and 1-5% pyrite (Fig. 10b). The composition of the black residuum is a combination of fine silt and carbonaceous material.

Decarbonatization of host limestone occurs synchronously with silicification. Quartz in silicified and mineralized zones is typically black in color with a distinct, sugary texture. Quartz can be abundant in mineralized areas, locally up to 95% by volume. Quartz crystals are variable, including both euhedral and anhedral crystals. The quartz crystals are typically very small, rarely greater than 1 mm with an average size of 0.05-0.4 mm. Anhedral crystals typically



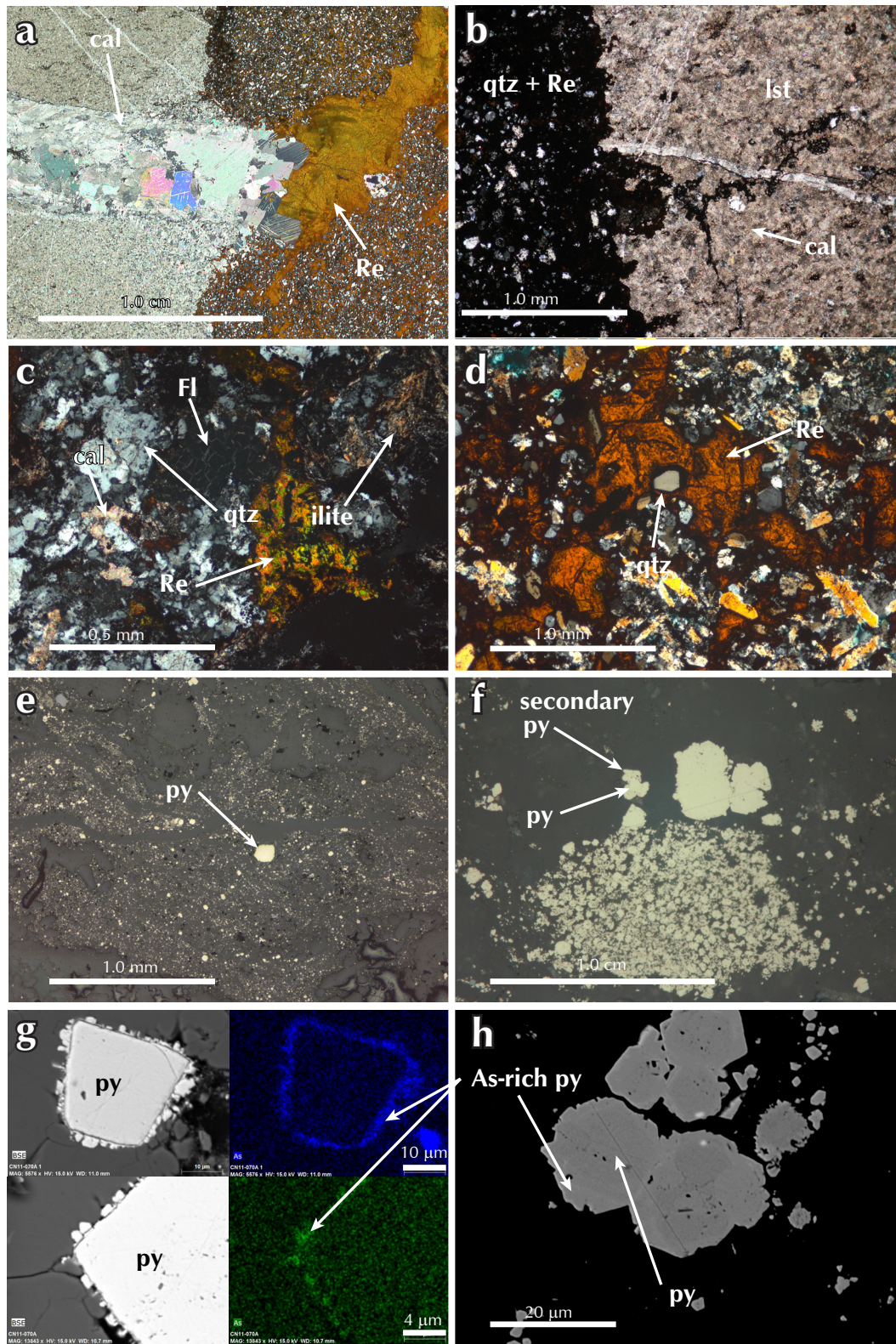
**Figure 9.** Gabbroic dyke units in Conrad: (a) photograph of gabbroic dyke with coarse crystalline amphibole; (b) photomicrograph of gabbroic dyke with coarse grained amphibole (amp; cpx=clinopyroxene, plag=plagioclase); (c) photograph of amygdaloidal unit with porphyritic plagioclase; and (d) photomicrograph of dyke illustrating carbonate amygdules and sericite (ser) altered plagioclase phenocrysts.

have inclusions of carbonate or dark colored residuum (Fig. 10c). Areas of mineralization are dominated by strong silicification, allowing areas of complete decarbonatization to remain moderately competent, permeable, and porous.

Pyrite can be abundant in mineralized zones. Pre-ore stage pyrite is concentrated within these zones as residuum from decarbonatization. Pyrite crystals are very small (<0.5mm), occurring as very small framboids, euhedral crystals, or anhedral grains/masses. Pyrite content within mineralized zones can be around 5-10% (Fig. 10e). The large increase in the amount of pyrite provides a suitable nucleus for later trace-element and gold-rich pyrite (Fig. 10e). Secondary growth around early crystals of pyrite is commonly visible (Fig. 10f). This secondary growth can be arsenic and trace-element enriched. Arsenian pyrite forms as secondary growths around early pyrite crystals (Fig. 10h).

The secondary arsenian pyrite is very small, commonly only 1-5 microns in size; and locally forms anhedral buds or euhedral growths around pre-existing pyrite crystals (Fig. 10h,g). Despite a significant abundance, pyrite is not readily visible in hand specimens, probably because of its dark, sooty colour. Where observed petrographically, the highest abundance of pyrite is commonly associated with areas of increased illite content.

Visible gold is not present within the Conrad zone, although other minerals that can be recognized in hand specimen can be key indicators of gold enrichments. Realgar and orpiment are key spatial indicators of gold mineralization. In silicified and brecciated mineralized zones these arsenian sulphides are commonly observed disseminated within pore spaces or filling interstices (Fig. 10d). Massive realgar, orpiment, and fluorite are



**Figure 10.** Styles of mineralization in the Conrad zone: (a) photomicrograph of silicification and decarbonatization front next to un-altered limestone; (b) photomicrograph of alteration along stylolites and vein selvages (Re=realgar); (c) photomicrograph of mineralized textures and mineral varieties (Fl=fluorite); (d) photomicrograph illustrating early quartz surrounded by late realgar; (e) photomicrograph showing pyrite abundance in mineralized zones; (f) photomicrograph showing secondary pyrite growth around earlier pyrite; (g) SEM backscattered electron microscope images and corresponding arsenic map illustrating arsenic-rich overgrowths around early pyrite; and (h) SEM backscattered electron microscope image illustrating early pyritic cores with secondary trace element rich pyrite overgrowths.

commonly observed, but rarely contain significant gold. Massive realgar can be associated with peripheral rhombohedral calcite veins up to 3 m thick. Rare, narrow stibnite veins and veinlets are also present within siliciclastic packages. Although not always directly associated with gold, stibnite veins containing realgar, orpiment, and fluorite, serve as important indicators of possible gold mineralization. The pathfinder element mineral suite associated with mineralization in the Conrad zone is a key indicator to otherwise non-visible gold.

### DISCUSSION

Gold mineralization within the Conrad zone is intimately associated with decarbonatization of host limestone and

subsequent silicification. It is associated with a variety of minerals including realgar, orpiment, quartz, illite, fluorite, and calcite (Fig. 11). Very fine grained arsenic-rich pyrite typifies areas of gold mineralization. Texturally, zones of gold mineralization appear as black breccias or replacement/dissolution zones, typically occurring with abundant visible realgar.

### DISTRIBUTION OF MINERALIZED ZONES

The factor controlling the distribution of alteration and mineralization is permeability. The core of mineralization appears to define a large antiformal structure within the Conrad limestone (Fig. 5); however, a combination of factors controls the permeability of the rock. Apart from primary fluid conduits such as fault and shear zones,

Feature	Host Rock Features	Pre-Au	Au Stage
stylolites 1 <sup>st</sup> gen stylolites 2 <sup>nd</sup> gen stylolites 3 <sup>rd</sup> gen calcite veins 1 <sup>st</sup> gen calcite veins 2 <sup>nd</sup> gen calcite veins 3 <sup>rd</sup> gen folds			
pyrite dolomite sphalerite			
decarbonatization quartz (silicification) arsenian pyrite illite gold			
realgar orpiment fluorite stibnite calcite			

Figure 11. Preliminary paragenetic scheme for Conrad zone mineralization, illustrating early rock preparation events followed by late ore stage mineralization.

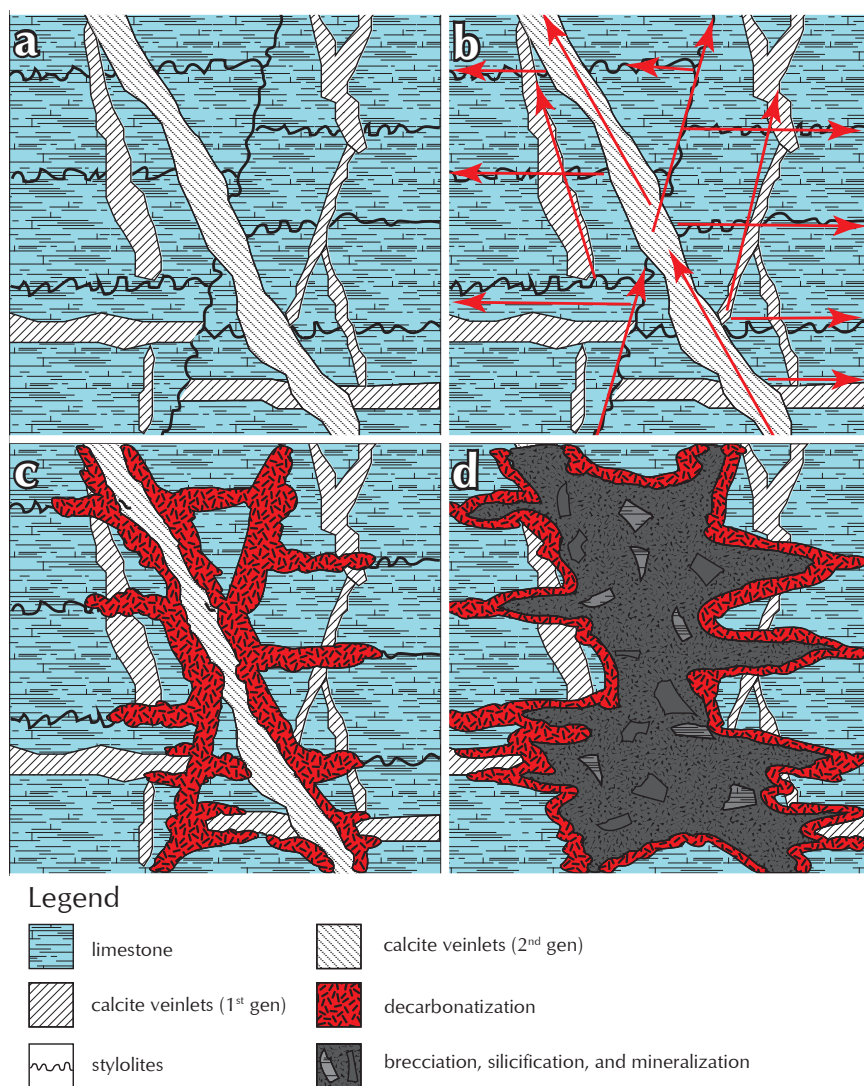
features controlling permeability are stylolites, veinlets, fold hinges and faults (Fig. 10b). Three generations of stylolites are present within the Conrad limestone. Up to four generations of calcite veins and veinlets are also present within the host limestone. Small scale folds are readily observed throughout the Conrad limestone package, many of which have faults and fractures propagating through fold hinges. These features create preferential fluid pathways for mineralizing fluids. The network of porosity created by the stylolites, vein sets, fold hinges, and isolated shears and faults control the distribution and intensity of mineralization and alteration. Permeability is possibly further enhanced in the limestone within the axial area of the anticline by the hydraulic barrier presented by the overlying siliciclastic package.

### FLUID EVOLUTION MODEL

Alteration associated with gold mineralization at the Conrad zone consists of two primary phases: decarbonatization and silicification (Fig. 12). The strongest control on the distribution of mineralization is porosity and permeability. Exploitation of the porosity network by the mineralizing fluid has enabled reaction with and removal of carbonate from the host limestone. As this process progressed, varying amounts of carbonate were removed and quartz crystallized into space created by the removal of carbonate. The quartz that is present is commonly euhedral, indicating precipitation after space was created (Fig. 10d). The process of gradual removal of carbonate around areas of high porosity resulted in the local formation of collapse breccias (Fig. 12). Euhedral as well as finely crystalline quartz now forms the matrix of these brecciated zones along with illite and late realgar, calcite, and fluorite (Fig. 11). Fluid exploitation of porosity networks gave rise to extensive decalcification, followed by silicification of the host carbonate rocks. In extreme cases, this process resulted in the formation of mineralized breccias (Fig. 12). These areas form the core of mineralized zones identified at Conrad.

### CONCLUSIONS

This paper presents the first descriptions of the host rocks and mineralized rocks from the Conrad zone, a newly discovered sediment hosted gold prospect in east-central Yukon. The Conrad zone is located in on the northern margin of the Selwyn basin proximal to the Dawson thrust, a major structure at the interface of Selwyn basin and MacKenzie platform. Geology of the Conrad zone is dominated by slope facies carbonate and clastic rocks with gold preferentially hosted within secondary arsenian pyrite in the carbonate rocks. Mineralization consists of



**Figure 12.** Fluid evolution model showing sequential stages of alteration and mineralization, including, (a) early deformation events modifying the original permeability structure of the host rock; (b) preferential fluid flow along early veins and stylolites; (c) early phase of decarbonatization along early fluid pathways; and (d) final stages of decarbonatization, mineralization, silicification and brecciation.

decarbonatization, silicification, and subsequent gold deposition; realgar, orpiment, calcite, and fluorite are commonly observed as post mineralization open space minerals. The regional tectonic setting and local features at Conrad are similar to sediment hosted gold deposits found in the Carlin trend of Nevada in that gold is hosted in silty carbonate and intimately associated with arsenian pyrite growth rims around early pyrite. Based on detailed core logging, surface mapping, and laboratory work on both host rocks and mineralized zones we suggest the Conrad zone is a Carlin-type gold deposit.

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