Structural geology of the Nadaleen Trend, northeastern Yukon Territory, Canada: Implications for recent Au discoveries

Justin C. Palmer and Yvette D. Kuiper

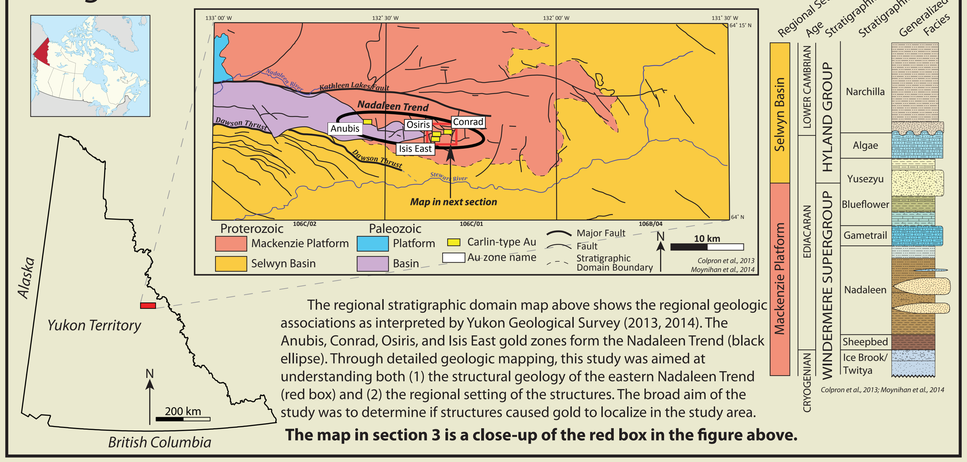
Department of Geology and Geological Engineering, Colorado School of Mines

1. Abstract

Recent Au discoveries in the eastern Nadaleen Trend of northeastern Yukon Territory are hosted in strongly deformed, unmetamorphosed, Neoproterozoic carbonate and siliciclastic rocks and display characteristics similar to Carlin-type deposits in Nevada. The complicated structural geology primarily results from mid-Cretaceous, thin-skinned fold-thrust deformation imposed upon a mechanically heterogeneous package of sedimentary rocks. Four generations of deformation resulted in tilting of stratigraphy to the SSW (D1), several moderately- to steeply-SSW-, SW- and E-plunging hundred-meter scale chevron folds and the E-trending dextral Osiris Fault (D2), the N-dipping reverse Nadaleen Fault zone (D3), and the N-trending dextral Conrad Fault (D4). Similar combinations of structures have not been recognized regionally, perhaps because the Nadaleen Trend is located in a zone of regional stratigraphic and structural transitions. Neoproterozoic- and Paleozoic-aged platform rocks occur west and north of the Nadaleen Trend; similarly aged basinal rocks occur to the east and south. Regionally extensive east-trending thrust faults, including the Dawson Thrust and Kathleen Lakes Fault, end within 10 km of the Nadaleen Trend. The combination of S-vergent thrust faults at and north of the Nadaleen Trend, and N-vergent thrust faults elsewhere in the region have the geometry of an E-trending triangle zone across the Nadaleen Trend. We suggest that these geologic transitions reflect the influence of a previously unrecognized, south-dipping basement normal fault (the Rackla Fault) that occurs west of the Nadaleen Trend and terminates below it. This fault is interpreted to have enough offset west of the Nadaleen Trend to obstruct north-directed fold-thrust movement, resulting in a lack of significant shortening to the north. The triangle zone is interpreted as a result of north-directed motion interacting with and overriding the minor obstruction at the eastern end of the Rackla Fault. Overriding the obstruction may have led to tectonic wedging and backthrusting. East of the Nadaleen Trend, fold-thrust movement was unobstructed.

Antiformal SSW-plunging D2 structures host the Conrad, Osiris, and Isis East Au zones within the eastern Nadaleen Trend. The folds are oriented oblique to the general easterly trend of folds and thrust faults in the region. Their oblique orientation perhaps made them act as locally favorable channels for upwelling ore fluids, while the E-trending triangle zone across the Nadaleen Trend may have acted as a more regional structural funnel.

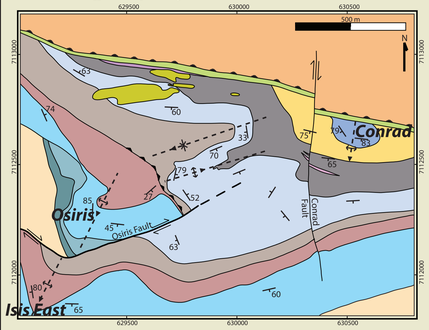
2. Regional Location



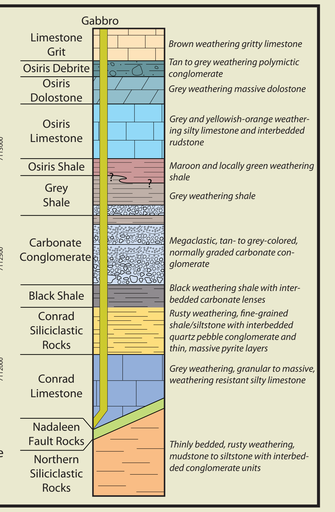
The regional stratigraphic domain map above shows the regional geologic associations as interpreted by Yukon Geological Survey (2013, 2014). The Anubis, Conrad, Osiris, and Isis East gold zones form the Nadaleen Trend (black ellipse). Through detailed geologic mapping, this study was aimed at understanding both (1) the structural geology of the eastern Nadaleen Trend (red box) and (2) the regional setting of the structures. The broad aim of the study was to determine if structures caused gold to localize in the study area.

The map in section 3 is a close-up of the red box in the figure above.

3. Geologic Map and Stratigraphy

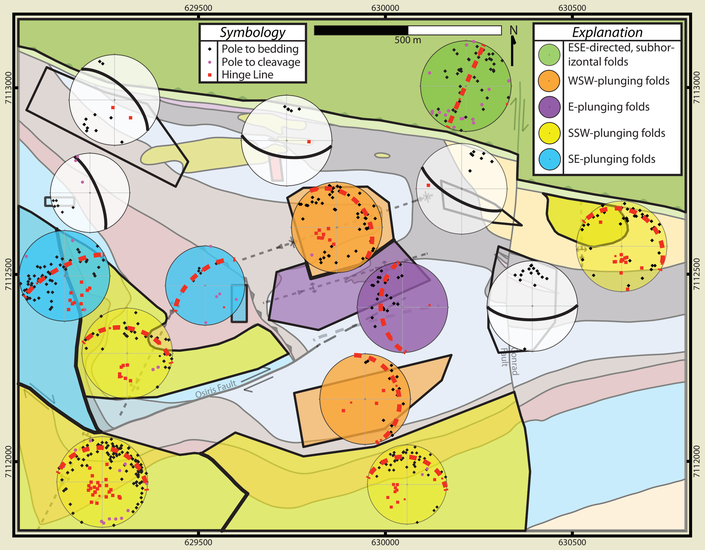


The geologic map above shows the general locations of fold axial traces, fault traces, and Au zones (bold italics). Three faults exist: the reverse Nadaleen Fault and the strike-slip Osiris and Conrad faults. Five map scale folds exist; three of which host the Conrad, Osiris, and Isis East Au zones.



4. Local Structural Geology

The geologic map of the eastern Nadaleen Trend to the right is separated into domains (black polygons) that correspond to areas defined by unique structural orientations. Structural measurements are displayed on equal-area, lower hemisphere projections and colored based on similar orientations.



1. Observation

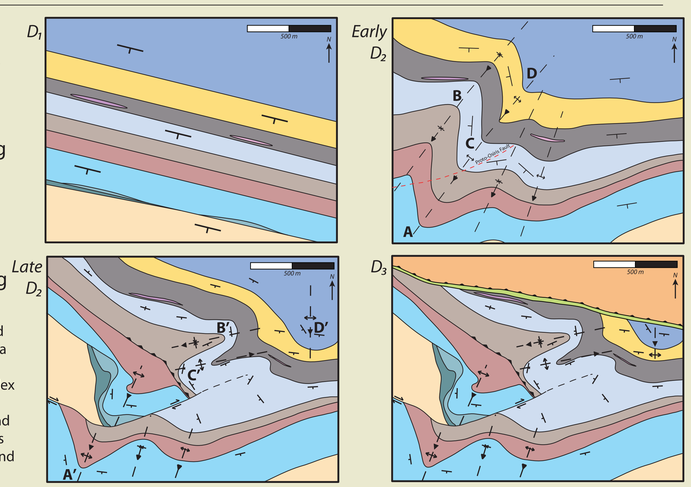
The area hosts moderately WSW-plunging folds (orange), moderately E-plunging folds (purple), shallowly to moderately SE-plunging folds (blue), moderately to steeply SSW-plunging folds (yellow), and SSE-directed, subhorizontal folds (green) as well as generally planar bedding (white). Open to tight chevron folds occur at all scales. The Conrad, Osiris, and Isis East Au zones are all hosted within moderately to steeply SSW-plunging folds. Fracture and stylolitic cleavage is common to fine-grained siliciclastic and carbonate units, respectively.

2. Interpretation

The sequence to the right shows our interpretation of the structural evolution of rocks of the Nadaleen Trend. Letters show similar locations from early D_2 to late D_2.

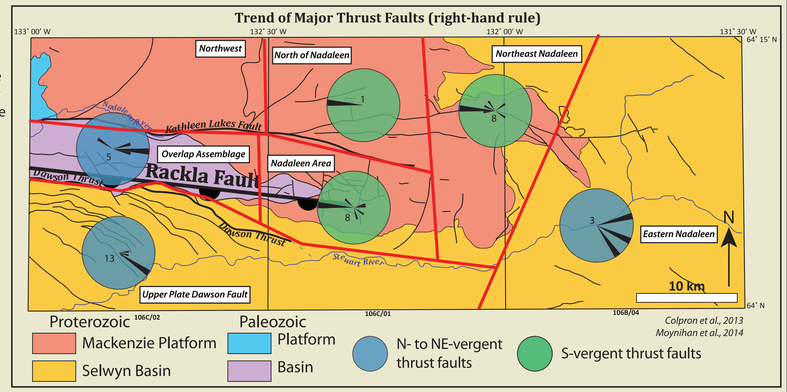
D_1: NNE-directed shortening
Early D_2: NW-directed, dextral simple shear
Late D_2: Continued NW-directed dextral simple shear
D_3: NNE-directed shortening

We interpret that early D_2 (NW-directed shortening) shortened the rock package to a breaking point at which the Osiris Fault formed, displacing strata to the east. Complex structural orientations throughout the area may be the result of rotation, translation, and thickening exploiting competency contrasts between relatively strong limestone units and weaker shale units.



5. Regional Structural Geology

The stratigraphic domain map to the right is separated into structural domains (red lines, white labels) with unique structural orientations to show the trends of thrust faults in the Nadaleen region. Thrust fault trends are shown as colored rose diagrams in the domains; colors correspond to unique directions of vergence. The number in the rose diagram corresponds to the number of thrusts mapped. No thrust faults were mapped in the *Northwest* domain.



1. Observation

Two dominant directions of vergence:
1. S-vergent thrusts generally at and north of the *Nadaleen Area*
2. N- to NW-vergent thrusts generally west, south, and east of the *Nadaleen Area*

Northward transition west of the Nadaleen Area
1. 0 thrusts in the *Northwest* domain
2. 5 thrusts in the *Overlap Assemblage*
3. 13 imbricate thrusts in *Upper Plate Dawson Fault*

Eest of the Nadaleen Area
1. N- to NE-vergent thrusts throughout *Eastern Nadaleen*

2. Interpretation

Triangle zone across Nadaleen Trend

N- to NW-vergent thrust faults to the south and S-vergent thrust faults to the north suggests 'triangle zone' geometry across the Nadaleen Trend similar to the geometry in the figure to the right. A triangle zone could have acted as a structural funnel for Au-rich ore fluids.

Rackla Fault

Regional-scale transitions that occur near the Nadaleen Area:
1. Eastern termination of the Dawson Thrust and Kathleen Lakes Fault
2. Termination of Mackenzie Platform and beginning of Selwyn Basin to the east and south
3. Eastern termination of Paleozoic platform and basin rocks
4. Transition from N- to NW-vergent thrust faults throughout the region to S-vergent thrust faults

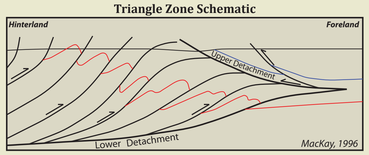
These large scale transitions are interpreted to have been influenced by a previously unrecognized subsurface normal fault, the "Rackla Fault," that is interpreted to end below the Nadaleen Area (figure above).

The magnitude of offset along the Rackla Fault west of the *Nadaleen Area* may have obstructed N-directed fold thrust movement, resulting in no thrust faults north of the *Overlap Assemblage*.

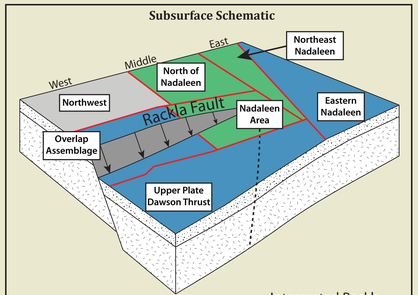
In the *Nadaleen Area*, the Rackla Fault is interpreted as a small barrier; overriding the barrier during continued N-directed thrusting detached rocks in the foreland through wedging, thrusting them to the south.

Unobstructed thrusting occurs east of the *Nadaleen Area*.

Triangle Zone Schematic



Subsurface Schematic



6. Conclusions

Local

Large-scale structural features include:
1. Several hundred-meter scale, open to tight chevron folds that plunge moderately to steeply to the SSW, SW, and E.
2. The E-trending dextral strike-slip Osiris Fault
3. The steeply NNE-dipping Nadaleen Fault zone

Interpreted deformation events
D_1: NNE-directed shortening
D_2: NW-directed shortening
D_3: N-S directed shortening

Regional

Structural features:
1. N- to NE-vergent thrust faults west, south, and east of *Nadaleen Area*
2. S-vergent thrust fault at and north of *Nadaleen Area*

Interpretation
1. The Nadaleen Area lies in the center of a triangle zone.
2. The Rackla Fault caused obstruction of thrusting to the west of, formation of a triangle at, and unobstructed movement east of the *Nadaleen Area*

7. Acknowledgements

Rob and Joan Carne and Julia Lane are graciously thanked for their constant good advice and humor in the field, and for supporting the master's thesis project.

Odin Christensen is thanked for his advice and support in the field.

We thank Venessa Bennett for her contact with ATAC Resources and for our field introduction.

Archer Cathro & Associates (1981) Ltd. and ATAC Resources Ltd. are thanked for their outstanding support in camp and for their generous financial support.

We thank Society of Economic Geologists for monetary support throughout this project.

8. References

MacKay, P.A., 1996, The Highwood Structure: A tectonic wedge at the foreland edge of the southern Canadian Cordillera: Bulletin of Canadian Petroleum Geology, v. 44, p. 215-232.
Colpron, M., Moynihan, D., Israel, S., and Abbott, G., 2013, Bedrock geology of the Rackla belt (106C/1-4 and 106D/1), southern Nadaleen map area, Yukon Geological Survey: Poster presented at 2013 AME BC Mineral Exploration Roundup Conference, Vancouver, B.C., January 28-31, 2013.
Moynihan, D., Colpron, M., Israel, S., and Abbott, G., 2014, Geology of the eastern Rackla Belt, east-central Yukon, Yukon Geological Survey: Poster presented at 2014 Mineral Exploration Roundup Conference, Vancouver, B.C., January 27-30, 2014.