

Paleozoic stratigraphy, tectonics and metallogeny of the Pelly Mountains, Quiet Lake and Finlayson Lake map areas (NTS 105F and G), central Yukon: Project outline and preliminary field results

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ABSTRACT

Paleozoic rocks of the Pelly Mountains, central Yukon, preserve greater than 150 m.y. of sedimentation, magmatism and base-metal mineralization. To identify secular trends in regional tectonics and metallogeny, a multi-year project on the stratigraphy of the Pelly Mountains in the Quiet Lake (105F) and Finlayson Lake (105G) map areas was initiated. Field studies during summer 2015 focused on two stratigraphic intervals: (1) mafic volcanic, volcanoclastic and clastic rock successions assigned to the Cambrian-Ordovician Cloutier and Groundhog formations (Kechika group); and (2) felsic volcanic, volcanoclastic and clastic rock successions assigned to the Devonian-Mississippian Black Slate and Felsic Volcanic formations (Seagull group). Cambrian-Ordovician strata were deposited in a marine environment characterized by episodic mafic volcanism and extensional tectonism. Devonian-Mississippian strata record the transition from an extensional turbidite basin to a metalliferous volcanic rift basin, and resemble key rock assemblages of the Selwyn basin (Earn Group) and Yukon-Tanana terrane (Grass Lakes and Wolverine Lake groups).

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INTRODUCTION

The Pelly Mountains of central Yukon (Fig. 1a) have seen a long history of bedrock mapping, stratigraphic investigations and mineral exploration (e.g., Wheeler *et al.*, 1960a,b; Tempelman-Kluit *et al.*, 1976; Tempelman-Kluit, 1977, 2012; Gordey, 1981; Mortensen, 1982; Holbek and Wilson, 1997; Fonseca, 1998; Hunt, 2002). Field studies in the Quiet Lake (105F) and Finlayson Lake (105G) map areas, east of the South Canol Road and west of the Tintina fault (Fig. 1b), were in part driven by stratigraphic comparisons with rock units that host Cambrian-Ordovician and Devonian sedimentary exhalative (SEDEX) base-metal deposits in the Anvil (Faro, Grum, Vangorda

and others) and Macmillan Pass (Tom, Jason) districts and Devonian-Mississippian volcanogenic massive sulphide (VMS) base-metal deposits in the Finlayson Lake district (Wolverine, Kudz Ze Kayah, GP4F and others). Despite this attention, there are many outstanding questions about the precise age, tectonic setting and base-metal potential of regionally extensive Paleozoic rock assemblages. To investigate these and other questions, a multi-year study of mineralized, prospective and barren stratigraphic units was initiated in the Saint Cyr Range (central Pelly Mountains). The short-term goals of this project are to constrain the field geology, age, petrogenesis and geochemistry of Cambrian-Ordovician and Devonian-Mississippian rocks

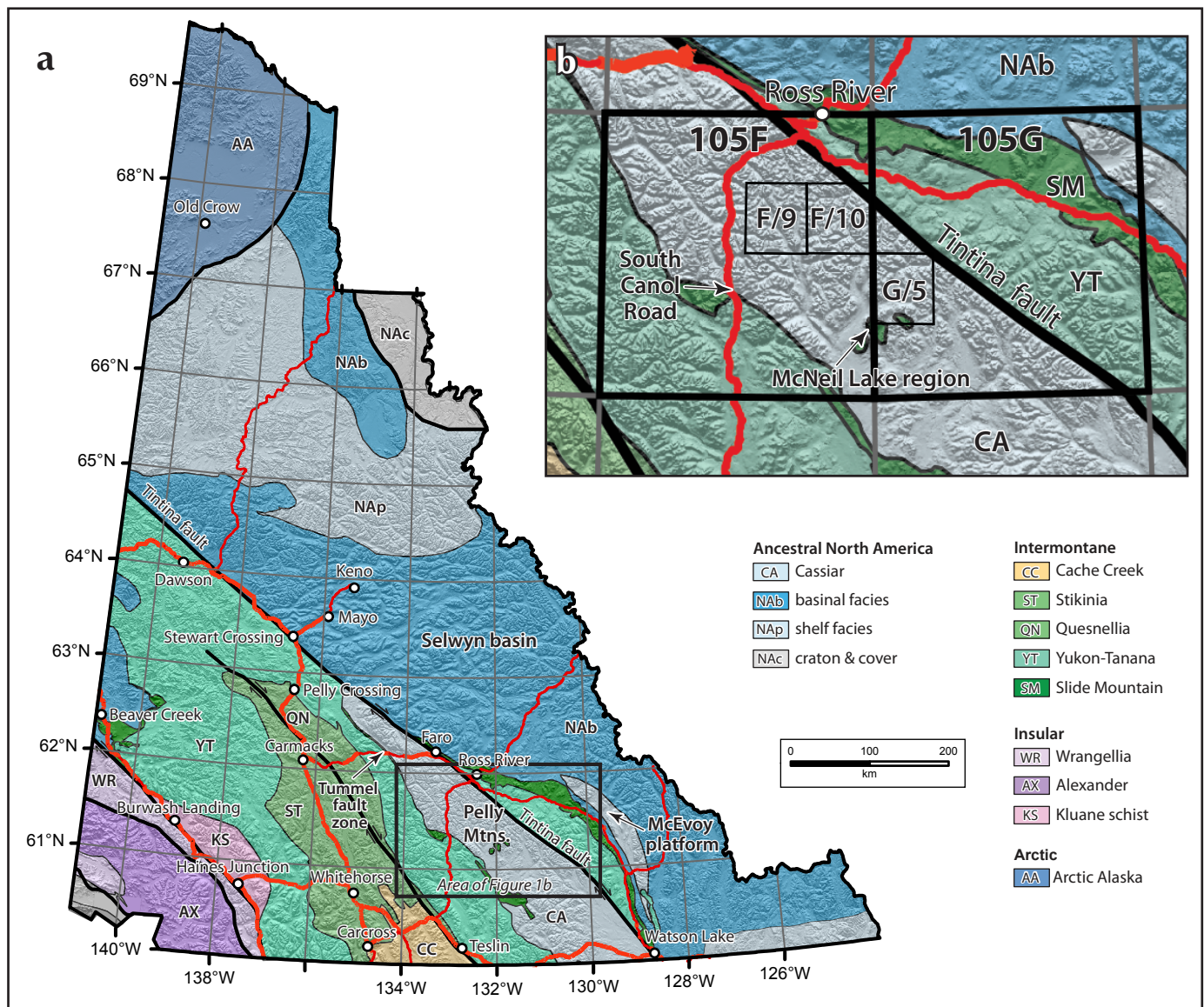


Figure 1. (a) Yukon bedrock geology and terrane map modified from Colpron and Nelson (2011). (a) Location of the Pass Peak (105F/9), Cloutier Creek (105F/10), and Mount Placid (G/5) map areas in the Pelly Mountains between the South Canol Road and Tintina fault.

in the Pass Peak (105F/9), Cloutier Creek (105F/10) and Mount Placid (105G/5) map areas (see Fig. 1b). The long-term objectives are to characterize secular trends in regional tectonics and metallogeny, especially those relevant to lithospheric architecture (e.g., Cecile *et al.*, 1997; Hayward, 2015), and identify genetic relationships with coeval Paleozoic strata of the Selwyn basin, Kechika trough and Yukon-Tanana terrane.

STRATIGRAPHIC FRAMEWORK

The Pelly Mountains are mostly underlain by the Cassiar terrane (CA in Fig. 1), a parautochthonous fragment of the ancient Pacific margin that has undergone at least 430 km of dextral displacement along the Tintina fault (Gabrielse *et al.*, 2006). Lower Paleozoic strata of the Cassiar terrane comprise a distinct paleogeographic feature referred to as the Cassiar or Pelly-Cassiar platform (Gabrielse, 1967; Fritz *et al.*, 1991) or Pelly high (Cecile and Norford, 1993) that was located to the west (seaward) of inboard passive margin elements (Selwyn basin, Kechika trough, Macdonald platform; see discussion in Gordey, 2013). Allochthonous units of the pericratonic Yukon-Tanana and Slide Mountain terranes that evolved to the west (seaward) of the North American autochthon during the mid to late Paleozoic occur in faulted contact with the Cassiar terrane along its western edge (*i.e.*, Tummel fault zone, Glenlyon map area; Fig. 1a; Colpron *et al.*, 2006) and as overlying klippen (*i.e.*, McNeil Lake region, Finlayson Lake map area; Fig. 1b; Gordey, 1981).

Tempelman-Kluit (2012) divided the Paleozoic stratigraphy of the Cassiar terrane into five depositional sequences within the Quiet Lake and Finlayson Lake map areas, which from oldest to youngest comprise the Ketzka, Kechika, Askin, Harvey and Seagull groups. Tempelman-Kluit (2012) concluded that many of these depositional sequences likely correlate with age-equivalent strata of the Cassiar terrane in northern British Columbia (Cassiar Mountains) or other passive margin elements in eastern Yukon. Figure 2 shows a schematic stratigraphic column for the study area.

KETZA GROUP

The oldest stratigraphic units in the Pelly Mountains are assigned to the Ketzka group. Named for excellent exposures near the headwaters of the Ketzka River, the group is at least 1000 m thick and contains a lower succession of Ediacaran(?)–Cambrian quartz sandstone, shale and limestone (Pass Peak formation), and an

upper succession of Cambrian calcareous shale and archaeocyathid-bearing limestone (McConnell River formation; Fig. 3a-d). Tempelman-Kluit (2012) concluded that the Ketzka group is correlative with the Atan Group (Boya and Rosella formations) of northern British Columbia.

KECHIKA GROUP

Tempelman-Kluit (2012) assigned Upper Cambrian–Ordovician strata of the Pelly Mountains to the Kechika Group based on apparent similarities with the formerly named Kechika Group (Gabrielse, 1963) in northern British Columbia. Gabrielse (1998) re-assigned such units in the Cassiar Mountains to the Kechika Formation. Herein, we refer to Upper Cambrian–Ordovician strata as the Kechika group (informal) because these units have not been formally defined according to the North American Stratigraphic Code.

The lower Kechika group comprises four laterally equivalent, interfingering sedimentary–volcanic facies (Ram, Groundhog, Cloutier and Gray Creek formations) that crop out across the Pelly Mountains (Fig. 2; Tempelman-Kluit, 2012). The Cloutier formation, named for exposures near Cloutier Creek, contains greater than 500 m of mafic lava and volcanoclastic rocks that represent the volcanic centre of the belt. To the northeast and southwest of the Cloutier Creek area, the Groundhog formation comprises greater than 800 m of shale to tuffaceous shale units that are intercalated with 1 to 8-m-thick sills of amygdaloidal basalt, pyroxene gabbro and sediment-matrix volcanic breccia (Figs. 2, 4a-d). The Ram formation occurs in the northeastern part of the facies belt and consists of up to 1000 m of platy limestone and calcareous shale. The Gray Creek formation is located in the southwestern part of the facies belt and comprises about 400 m of variably deformed and metamorphosed clastic rocks and minor mafic sills. The upper Kechika group is represented by black graphitic shale of the Magundy formation that overlies the Ram, Cloutier, and Groundhog formations in the Quiet Lake map area.

The depositional ages of Kechika group strata are constrained by Late Cambrian to Early Ordovician trilobites from the Ram formation and Ordovician graptolites from the Magundy formation (Tempelman-Kluit, 2012). Reconnaissance zircon U–Pb geochronology of a Groundhog formation pyroxene gabbro yielded a Late Cambrian age (L. Beranek and R. Friedman, 2015, unpublished data).

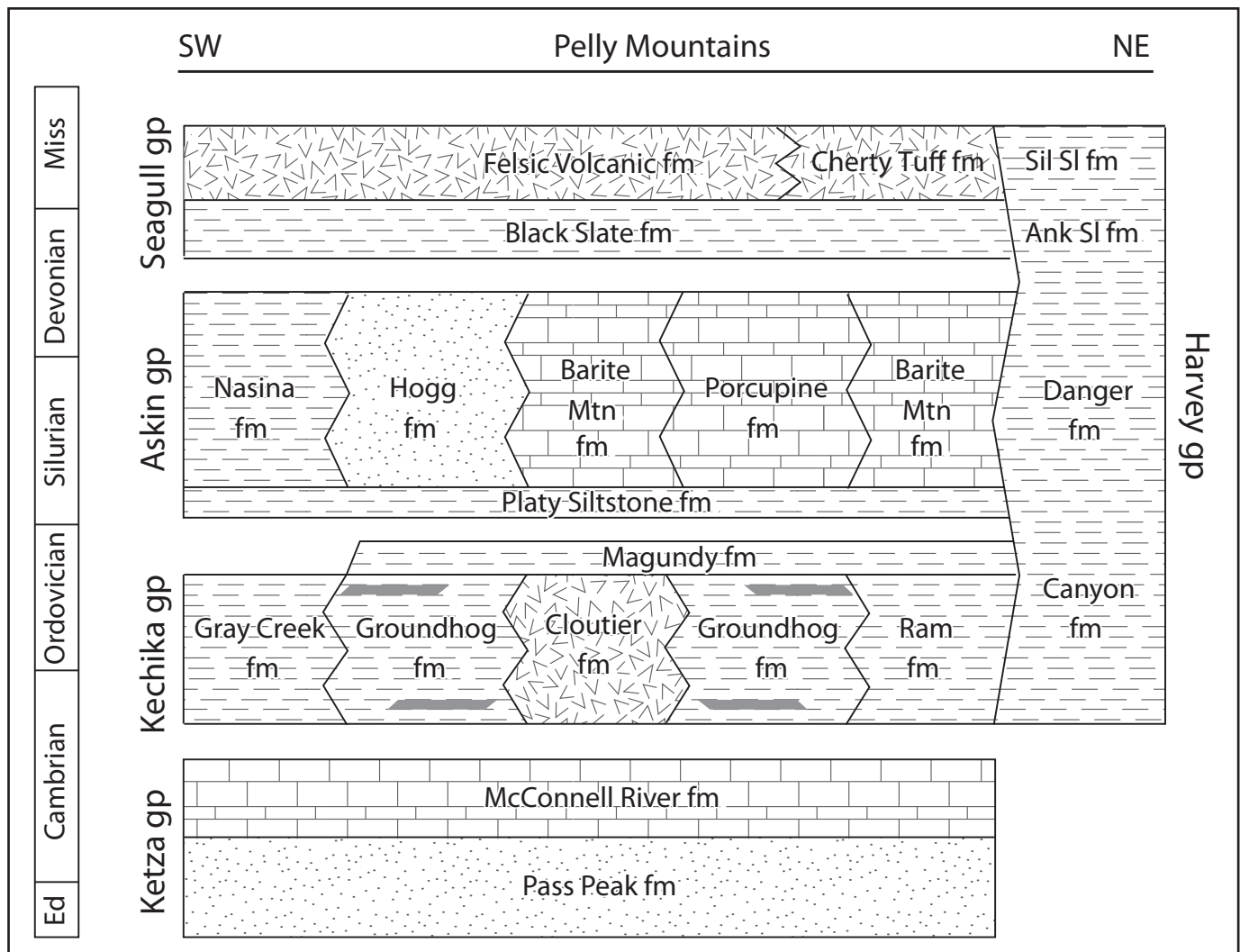


Figure 2. Paleozoic stratigraphy of the Pelly Mountains as compiled by Tempelman-Kluit (2012). Abbreviations: Ank=Ankerite; Ed=Ediacaran; fm=formation; gp=group; Miss=Mississippian; Mtn=mountain; Sil=Siliceous; and Sl=Slate.

ASKIN GROUP

The Silurian to Devonian Askin group (Figs. 2 and 5a,b) contains a basal succession of dolomitic siltstone and intermediate volcanic and volcanoclastic rocks (Platy Siltstone formation), a middle succession of four, laterally equivalent clastic-carbonate facies (Nasina, Hogg, Barite Mountain and Porcupine formations), and an upper succession of carbonate rocks (Grey Limestone formation; Tempelman-Kluit, 2012). The Askin group has a thickness of up to 1000 m. Tempelman-Kluit (2012) concluded that the Askin group is equivalent to rocks in the Cassiar Mountains (Sandpile and Ramhorn formations; Gabrielse, 1998), and may further correlate with Silurian-Devonian shelf strata of the McEvoy platform (Fig. 1a) to the northeast of the Tintina fault (see Gordey, 2013).

HARVEY GROUP

The Cambrian-Mississippian Harvey group (Fig. 2) is named for variably deformed and metamorphosed siliciclastic, carbonate and volcanic rocks that crop out between the Tintina and St. Cyr faults. Tempelman-Kluit (2012) interpreted that the lower two units (Canyon and Danger formations) correlate with the Kechika and Askin groups, respectively, whereas the upper two units (Ankeritic Slate and Siliceous Slate formations) represent basal parts of the southwestern Selwyn basin displaced by the Tintina fault.

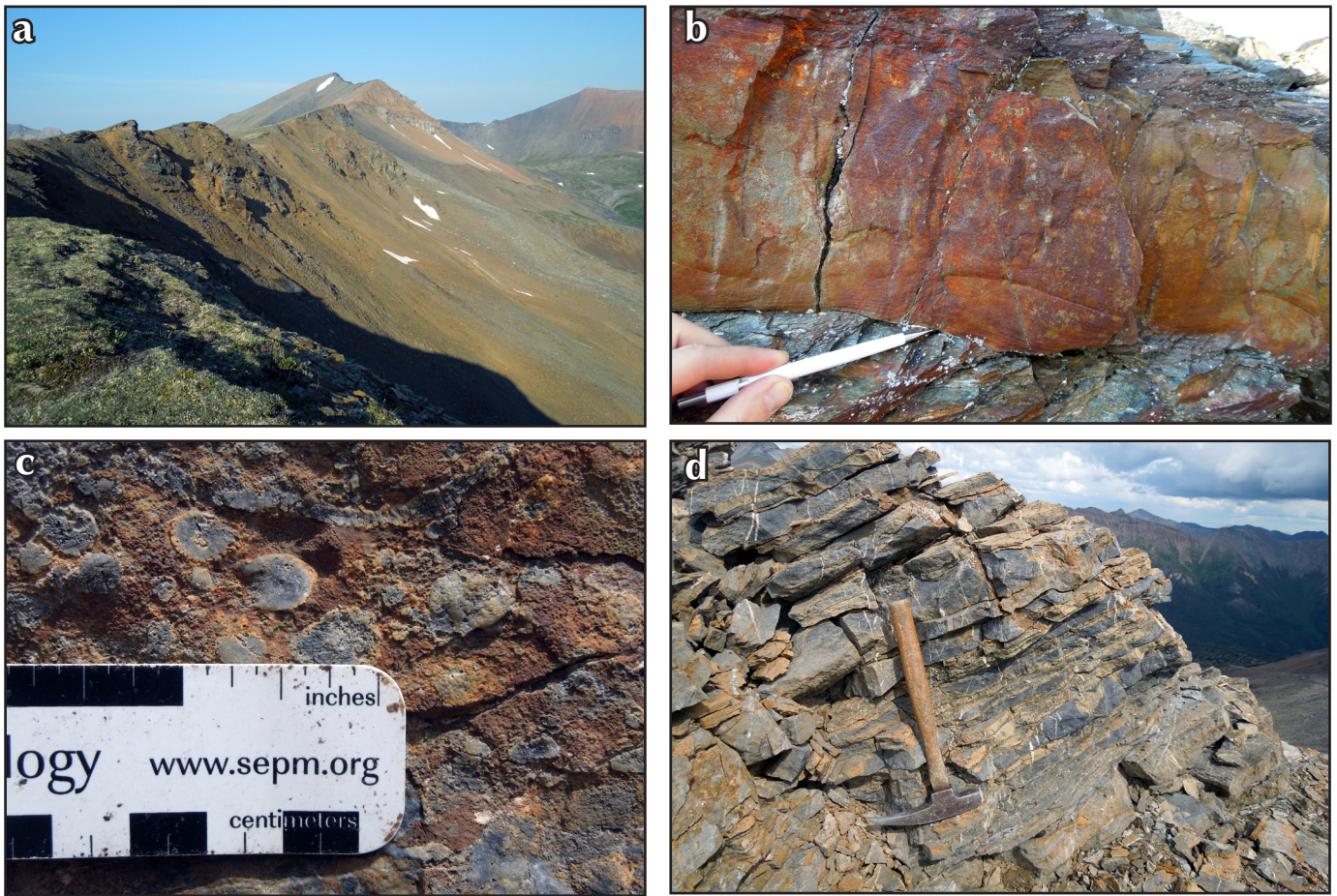


Figure 3. Field photographs of Ediacaran(?)–Cambrian Ketzan group strata, Pelly Mountains. (a) West-directed view of Pass Peak and McConnell River formation strata exposed at the Ketzan River Mine, Pass Peak map area; (b) parallel laminated, medium-bedded sandstone and enclosing shale of the Pass Peak formation, Ketzan River Mine area; (c) variably recrystallized archaeocyathid fossils in McConnell River formation limestone, Ketzan River Mine area; and (d) thin to medium-bedded limestone and silty limestone of the McConnell River formation, Ketzan River Mine area.

SEAGULL GROUP

The Seagull group is named for Upper Devonian to Mississippian strata that are well exposed in the upper parts of Seagull Creek, central Quiet Lake map area (Tempelman-Kluit, 2012). The Black Slate formation (Fig. 2) occurs at the base of the group and contains up to 500 m of shale, lithic sandstone and chert pebble conglomerate, and minor volcanic rocks, limestone and thin-bedded barite. The overlying Felsic Volcanic formation (Figs. 2 and 6a-c) comprises about 500 m of felsic lava flows and volcanoclastic rocks that mostly occur in a 400 km² region between Seagull Creek and Cloutier Creek. Felsic plugs, sills and dikes assigned to the Trachyte Member are cogenetic with Felsic Volcanic formation extrusive rocks. The Cherty Tuff formation (Figs. 2 and 6d) consists of siliceous tuff that is the lateral equivalent of the Felsic Volcanic formation.

Seagull group rocks are recognized hosts of Late Devonian–Early Mississippian VMS mineralization in the Quiet Lake and Finlayson Lake map areas (e.g., Mortensen, 1982; Holbek and Wilson, 1997). The timing of VMS mineralization and felsic magmatism in the Cassiar terrane is broadly coincident with that of the Selwyn basin and Yukon-Tanana terrane (Hunt, 2002). The Wolf deposit in the Mount Placid (105G/5) map area has received the most study and contains an inferred resource of over 4 million tonnes with grades of 6.2% Zn, 1.8% Pb and 84 g/t Ag (historic and not NI-43-101 compliant; Gibson *et al.*, 1999).

The depositional ages of the Seagull group are constrained by Late Devonian to Early Mississippian (Tournaisian to Viséan) conodonts within Black Slate and Felsic Volcanic formation limestone (Tempelman-Kluit, 2012).

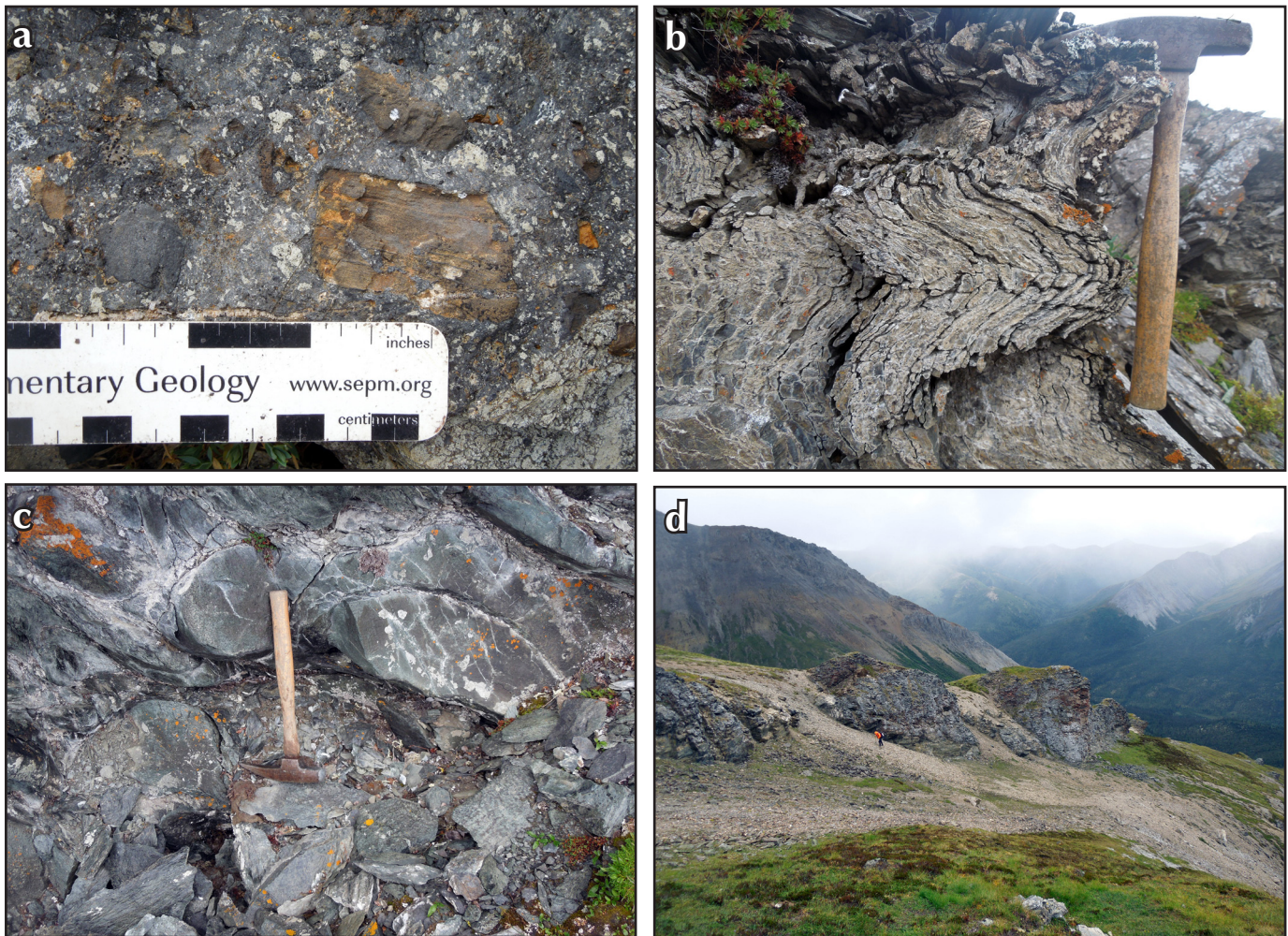


Figure 4. Field photographs of Upper Cambrian-Ordovician Kechika group strata, Pelly Mountains. (a) Groundhog formation sediment-matrix volcanic and sedimentary lithic breccia, near Ram Creek, Pass Peak map area; (b) tightly folded Groundhog formation shale, near Groundhog Creek, Pass Peak map area; (c) pillow basalt, Mount Placid map area; and (d) east-directed view of resistant, 8 m-thick gabbro sill and enclosing shale of the Groundhog formation, near Ram Creek, Pass Peak map area.

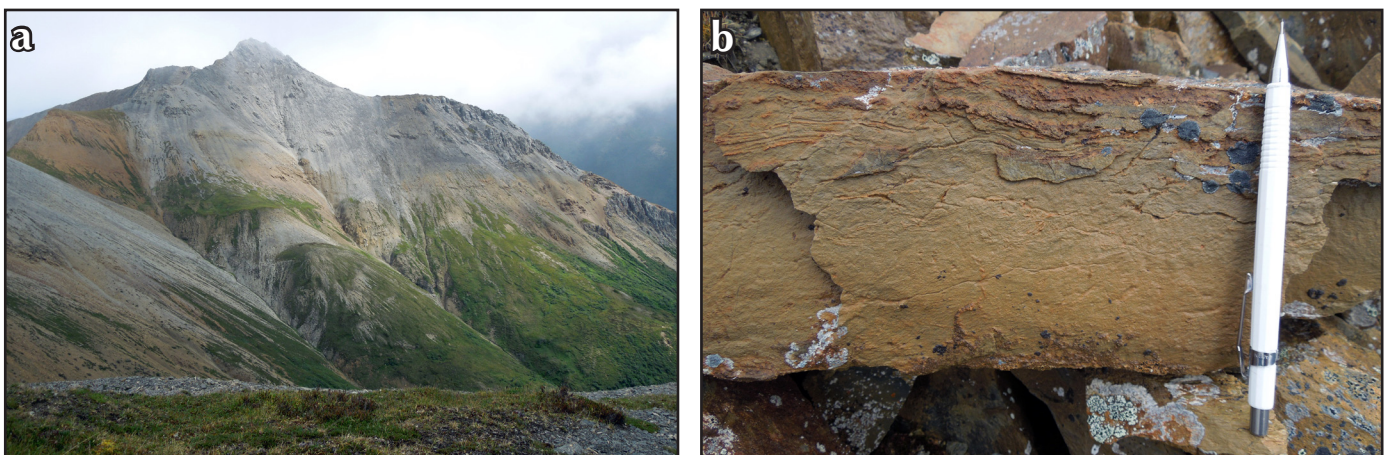


Figure 5. Field photographs of Silurian-Devonian Askin group strata, Pelly Mountains. (a) North-directed view of Porcupine formation dolomite, near Ram Creek, Pass Peak map area; and (b) orange-weathering, intermediate ash-flow tuff or reworked derivative, Orange Volcanics Member of the Platy Siltstone formation, near Ram Creek, Pass Peak map area.

Reconnaissance zircon U-Pb geochronology of a Felsic Volcanic formation rhyolite yielded an Early Mississippian age (L. Beranek and R. Friedman, 2015, unpublished data).

NEW FIELD STUDIES

Cambrian-Ordovician and Devonian-Mississippian stratigraphic successions were studied at several localities within the Pass Peak (105F/9), Cloutier Creek (105F/10) and Mount Placid (105G/5) map areas. Rock units were systemically sampled for whole-rock geochemistry and Nd-Hf isotope geochemistry, zircon U-Pb geochronology and thin section petrography. Folding and faulting of the rocks and significant coverage of vegetation hampered attempts for detailed stratigraphic measurement at most localities.

CAMBRIAN-ORDOVICIAN CLOUTIER FORMATION

Cloutier formation strata in the Cloutier Creek map area are best exposed along a southwest-trending ridge

approximately 10 km east of the Ketzka River Mine (Fig. 7a; base of section: zone 08V 654218E 6829014N NAD 83). Three principal lithofacies associations (basaltic, volcanogenic sedimentary and limestone-argillite) were identified at this locality. The basaltic facies association is related to the eruption of primary volcanic products and mostly comprises units of vesicular to amygdaloidal massive basalt (Fig. 7b), pillow basalt (Fig. 7c) and sediment-matrix basalt breccia (Fig. 7d) that are 2 to 10 m thick. The volcanogenic sedimentary facies association formed by the reworking of primary volcanic units and consists of up to 8-m-thick units of monomictic basalt breccia (Fig. 7e) and conglomerate (Fig. 7f). The limestone-argillite facies association is apparently restricted to the upper Cloutier formation and contains variably deformed argillite, limestone and granule to cobble polymictic (mafic intermediate volcanic rock, limestone) conglomerate (Fig. 7g).

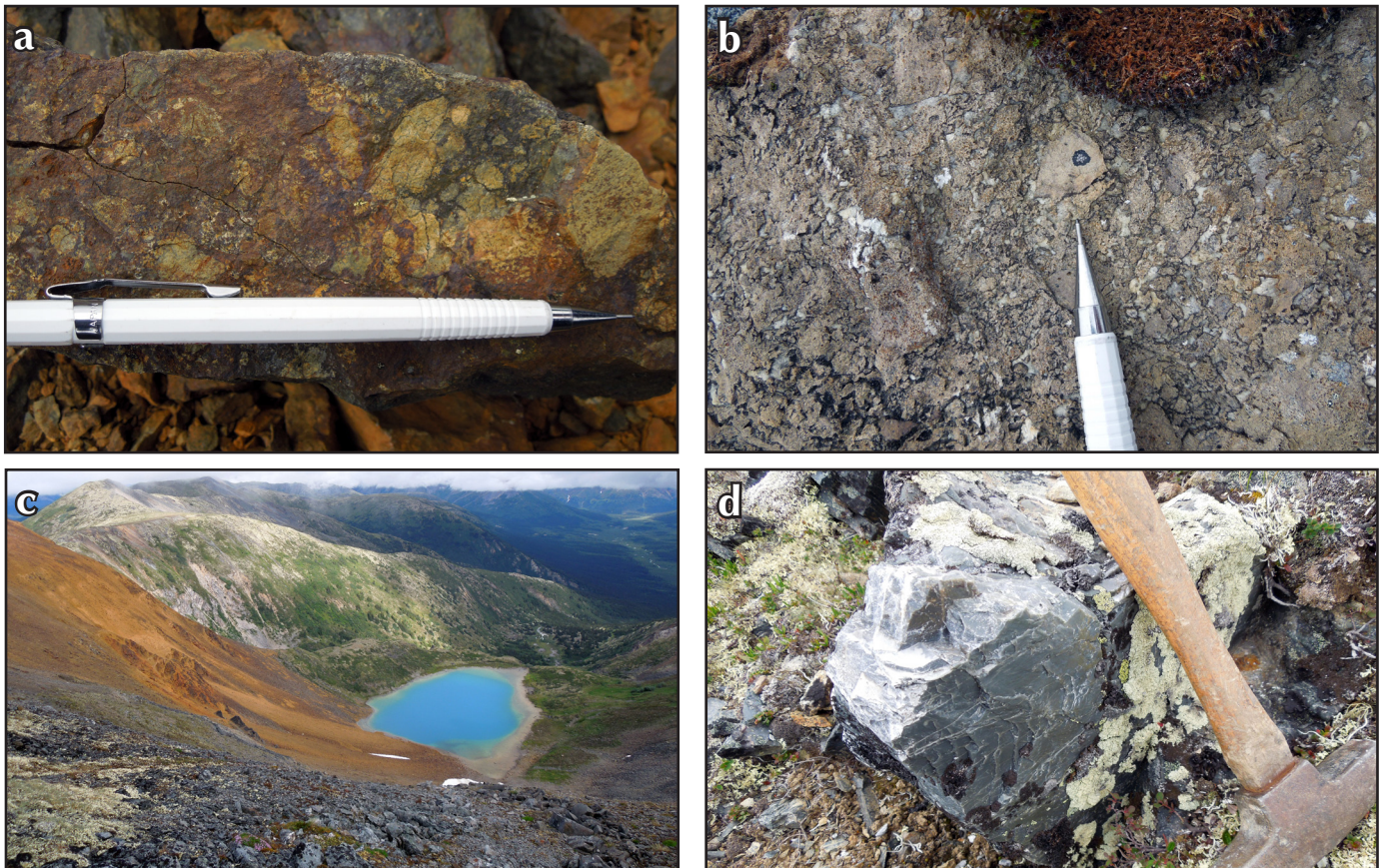


Figure 6. Field photographs of Upper Devonian-Mississippian Seagull group strata, Pelly Mountains. (a) Felsic volcanic breccia, Wolf deposit, near Mount Vermillion, Mount Placid map area; (b) lapilli tuff, near Cloutier Creek, Cloutier Creek map area; (c) north-directed view of gossan hosted in Felsic Volcanic formation strata, near Seagull Creek, Pass Peak map area; and (d) siliceous unit of the Cherty Tuff formation, headwaters of the McConnell River, Pass Peak map area.



Figure 7. Field photographs of the Cloutier formation, east of the Ketz River Mine, Cloutier Creek map area. Base of section – Zone 08V 654218E 6829014N NAD 83. (a) West-directed view of Cloutier formation strata, Ketz River Mine infrastructure visible in background; (b) amygdaloidal (chlorite) basalt; (c) vesicular pillow basalt; (d) sediment-matrix basalt breccia (fluidal peperite) consisting of amoeboid- to angular-shaped, lapilli-sized fragments in volcanoclastic matrix; (e) monomictic basalt breccia (hyaloclastite) with angular, lapilli to bomb-sized fragments in volcanoclastic matrix; (f) volcanic conglomerate; (g) sheared polymictic (limestone, mafic-intermediate volcanic rock) conglomerate; and (h) thin to medium-bedded silty limestone, near Cloutier Creek, Cloutier Creek map area.

The principal lithofacies of the Cloutier formation are consistent with a subaqueous depositional environment. Vesicular pillowed flows of the lower Cloutier formation are characteristic of subaqueous settings. Sediment-matrix basalt breccia units with lapilli-sized, amoeboid to angular-shaped clasts are likely fluidal peperites that formed from the emplacement of coherent mafic lava into/onto saturated sediment (e.g., Skilling *et al.*, 2002). Monomictic basalt breccia units with lapilli to bomb-sized clasts are probably resedimented hyaloclastites that were generated from quench fragmentation of coherent flows (e.g., Batiza and White, 2000). The presence of bedded limestone and limestone-bearing conglomerate units compares favourably to exposures of blue-grey carbonate and limy clastic rocks (Fig. 7h) in the upper Cloutier formation in the nearby Cloutier Creek area.

Preliminary geochemical results indicate that Cloutier formation strata yield non-arc, ocean island basalt-like (OIB) trace element and Nd-Hf isotope signatures. Age-equivalent strata of the Selwyn basin (Menzie Creek Formation, Anvil Range; Pigage, 2004) and Mackenzie platform (Marmot Formation, Misty Creek embayment; Leslie, 2009) yield analogous geochemical signatures. Our working hypothesis is that Cloutier formation mafic volcanic rocks (and mafic sills within the Groundhog formation) were generated by the partial melting of enriched lithospheric mantle during intermittent extension and rifting along the Cordilleran passive margin. Our future research will focus on the role of lithospheric architecture on Cambrian-Ordovician magmatism, including long-lived lithosphere-scale structures such as the Liard Line (Cecile *et al.*, 1997), which presumably influenced the magmatic history and metal fertility of the Pelly Mountains.

DEVONIAN-MISSISSIPPIAN BLACK SLATE AND FELSIC VOLCANIC FORMATIONS

Contact relationships between the Black Slate formation and overlying Felsic Volcanic formation are documented within an Upper Devonian-Lower Mississippian stratigraphic section that crops out near the headwaters of the McConnell River in the Pass Peak map area (base of section: zone 08V 627052E 6831980N NAD 83). The lowest stratigraphic levels of the Black Slate formation observed at this locality consist of dark grey shale with less than 2-m-thick beds of lithic sandstone and granule (shale chip) conglomerate. These strata are overlain by thin

to medium-bedded, tuffaceous to siliceous (cherty) shale with 1 to 3-mm-thick laminae of white-weathering volcanic ash (Fig. 8a). The tuffaceous component in the Black Slate formation apparently increases upsection.

The basal Felsic Volcanic formation conformably overlies Black Slate formation strata and comprises 15 to 20 m of grey shale and quartz eye to lithic lapilli tuff (Fig. 8b). A 10-m-thick unit of vesicular to amygdaloidal rhyolite overlies these basal volcanoclastic and clastic units. The rhyolite unit is distinctive for its resistant weathering character and large (up to 10 mm) cavities and quartz amygdales (Fig. 8c). The upper part of the Mississippian succession at this locality mostly consists of black shale, lapilli tuff and high-level intermediate to felsic stocks (Fig. 8d,e).

Felsic Volcanic formation igneous rocks have alkaline geochemical signatures that are consistent with felsic magmatism in a rift setting (Mortensen, 1982; Hunt, 2002; Beranek, 2015, unpublished data). Although there is abundant evidence for mid-Paleozoic extension-related magmatism along the ancient Pacific margin, many questions remain about the Late Devonian-Mississippian paleogeography of the Cassiar terrane and how it relates to coeval successions in the northern Cordillera. In the Selwyn basin of central and eastern Yukon, turbidite successions (shale, lithic sandstone, chert pebble conglomerate) assigned to the Earn Group were deposited during regional extension, intermediate to felsic magmatism, and VMS and SEDEX mineralization (e.g., Turner and Abbott, 1990; Gordey and Anderson, 1993; Cobbett, 2014, 2015). In the Finlayson Lake district of the Yukon-Tanana terrane, rock units of the Grass Lakes and Wolverine Lake groups record Late Devonian-Mississippian magmatism, Earn-style clastic sedimentation and VMS mineralization related to continental arc rifting (e.g., Mortensen, 1992; Piercey *et al.*, 2004; Murphy *et al.*, 2006). We posit that Seagull group rocks of the Pelly Mountains likewise preserve the stratigraphic evidence for mid-Paleozoic extension along the ancient Pacific margin. Our working hypothesis calls for the Black Slate formation to comprise part of a turbidite basin that developed during regional extension and initial felsic volcanism, whereas the overlying Felsic Volcanic formation was deposited in a metalliferous volcanic rift basin that was located behind an adjacent continental arc system (Yukon-Tanana terrane).

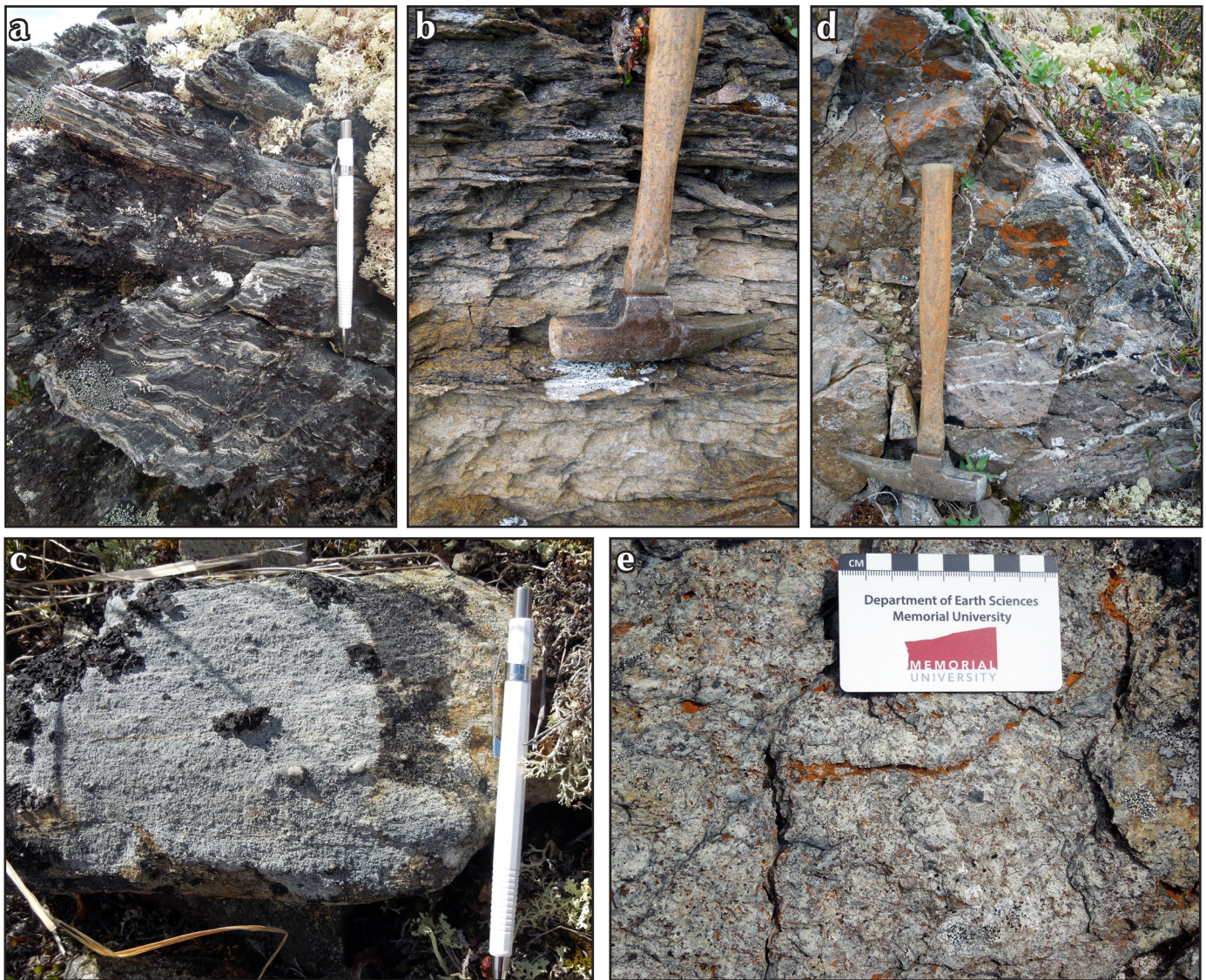


Figure 8. Field photographs of the Black Slate and Felsic Volcanic formations, headwaters of the McConnell River, Pass Peak map area. Base of section - Zone 08V 627052E 6831980N NAD 83. (a) Black Slate formation shale with 1-3 mm-thick laminae of white volcanic ash; (b) lapilli tuff near the base of the Felsic Volcanic formation; (c) amygdaloidal (quartz) rhyolite of the Felsic Volcanic formation; (d) intermediate to felsic rock of the Trachyte Member that is cogenetic with Felsic Volcanic formation strata; and (e) polymictic (sedimentary and volcanic lithic) breccia of the Felsic Volcanic formation.

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