Preliminary report on the bedrock geology of Castle Mountain area, Yukon (parts of NTS 105D/6)

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Abstract

Carbonate strata of the Cambrian to Devonian Bouvette Formation underlies the Castle Mountain area in central Yukon. Locally, within the Bouvette Formation, calcareous, fossiliferous clastic rocks are interstratified with volcaniclastic and volcanic rocks. The volcanic rocks are inferred to be post-early Silurian based on preliminary fossil ages of graptolites found in underlying limestone. I propose extensional tectonism temporarily disrupted carbonate platform development in the early Silurian in this area. Crustal extension resulted in normal faulting and local subsidence. Thermal uplift, related to underplating of igneous bodies, resulted in subaerial exposure and subsequent erosion of chert, carbonate and volcanic rocks. Basins and slopes (areas between thermally uplifted blocks and subsiding areas) collected material eroding from exposed strata and volcanic rocks deposited during eruptions.

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Introduction

Detailed mapping centred on Castle Mountain provides geologic context to Paleozoic volcanic rocks exposed in this area of central Yukon (Fig. 1). The volcanic rocks here are one of many occurrences of early to mid-Paleozoic magmatic rocks exposed in North American continental margin strata that are poorly characterized in terms of their age, environment of eruption and magma source (Goodfellow *et al.*, 1995; Colpron et al., 2016).

Published bedrock maps for this region are limited to 1:250 000 scale reconnaissance maps by Green (1972). In 2012, the Yukon Geological Survey initiated a targeted study aimed at better characterizing Paleozoic volcanic rocks exposed in Yukon. Since this project began, it has turned into a PhD project at Memorial University of Newfoundland undertaken in collaboration with the Yukon Geological Survey. The scope of the project has expanded outside Yukon to include Northwest Territories and Alaska as the ancient passive margin of western North America extends into these jurisdictions where notable Paleozoic volcanic rocks are exposed. This report summarizes the results of ten days of fieldwork, including geological mapping and sampling, from the Castle Mountain area (NTS 105D/6) in the summer of 2019, and represents the first publication of this multi-year project.

Geologic framework

Castle Mountain is located in the southern Ogilvie Mountains, between Hart River and Elliott Creek, approximately 200 km east-northeast of Dawson City (Fig. 1). In this area, a carbonate-dominated succession of relatively flat lying strata are part of the Ogilvie Platform, an arch that existed as part of the western Laurentian passive margin during the Cambrian to Devonian periods (Abbott, 1997; Cecile *et al.*, 1997). The Selwyn basin is located approximately 50 km to the south of Castle Mountain and is a deep water equivalent to the Ogilvie platform (Fig. 1a). The boundary between the two coincides with the Dawson fault, an east-west striking imbricated thrust fault. North of the Dawson fault, open folds, north and northwest trending steep faults, and a significant unconformity beneath the Cambrian to Devonian Bouvette Formation accounts for much of the map pattern in the area (Fig. 1b; Green, 1972).

Stratigraphy

Dolostone and limestone, and calcareous and volcanic-derived clastic rocks and minor mafic volcanic rocks of the Cambrian to Devonian Bouvette Formation and Cambrian to Silurian Marmot Formation, respectively, underlie the entire map area (Fig. 1b; Colpron *et al.*, 2016; Green, 1972).

In this report, we subdivide the Bouvette Formation into carbonate and deep water facies including three informal formations. Starting at the lowest stratigraphic level, these comprise 1) dolostone, 2) limestone, and 3) dolostone (Fig. 2). The Marmot Formation, termed the volcano-sedimentary facies below, forms an intermediate unit within the Bouvette Formation and is subdivided into sandstone, agglomerate, volcanic breccia, basalt and tuff (Fig. 2).

Dolostone–ЄOd, ЄOs

Buff and light grey weathering, thick-bedded to massive dolostone comprise the lower slopes of Castle Mountain and adjoining ridges (Figs. 2 and 3a). One distinct horizon of silicified stromatolite occurs approximately 90 m from the top of the dolostone and is an important marker bed (Fig. 3b and 4). The stromatolite structures range in size from 10–30 cm in diameter and form a bed approximately 30 cm thick (Fig. 3b). Locally, on the north side of Castle Mountain, orange-buff weathering, grey fresh, medium-bedded, quartz-rich dolomitic sandstone interbedded with orange weathering, green fresh, laminated mudstone crops out structurally below the dolostone and has been included within this member, although it may represent an older formation.

A minimum thickness of this unit is approximately 365 m. The base of the member is not exposed except where the dolomitic sandstone and mudstone crop-out, but the relationship between these rocks and the dolostone is unclear. The upper contact with limestone and chert is conformable and abrupt (Fig. 4).

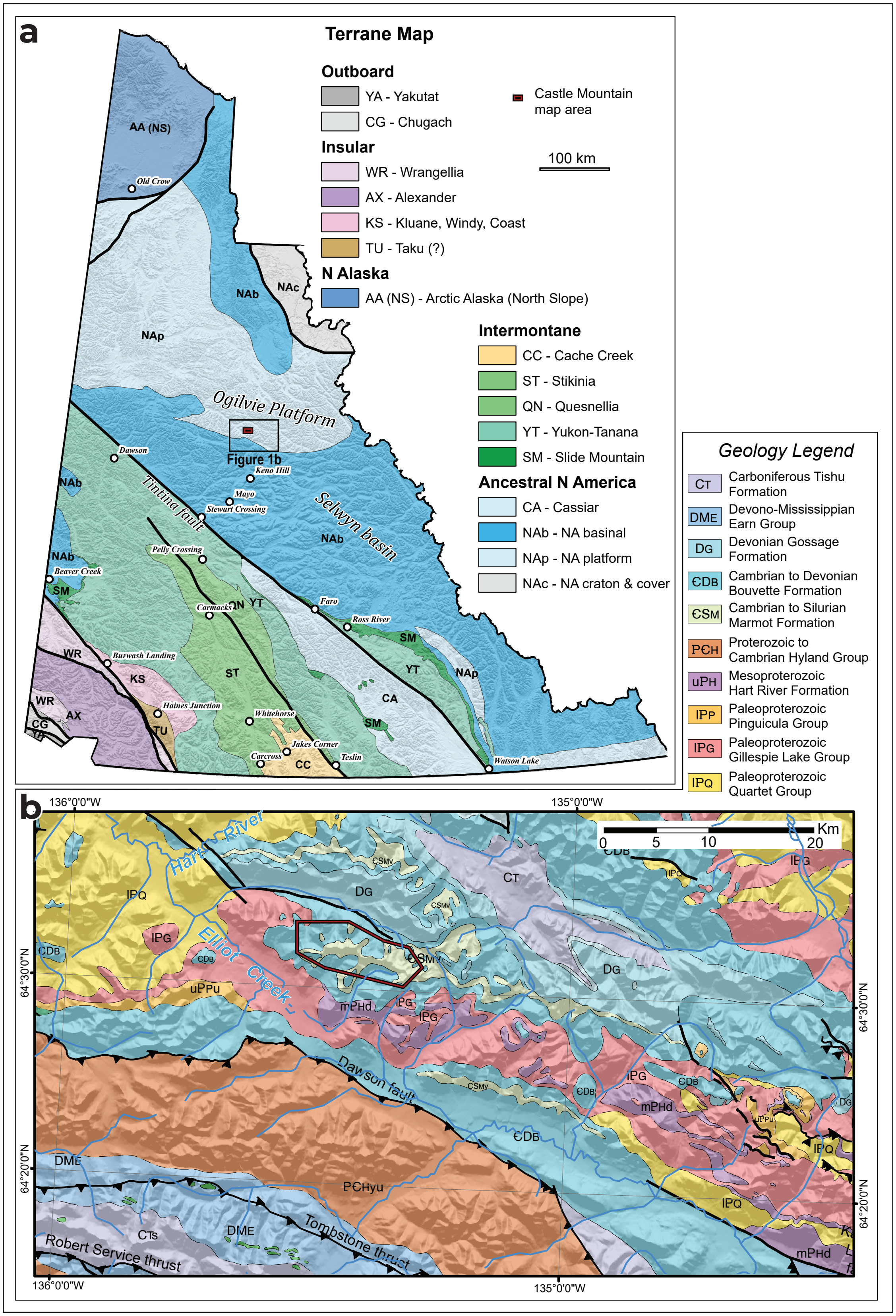

Figure 1. ***(a)*** *Terrane map of Yukon illustrating the location of map area presented in this report. Modified from (Colpron and Nelson, 2011).* ***(b)*** *Inset provides regional geology of the Castle Mountain area (Colpron et al. 2016).*

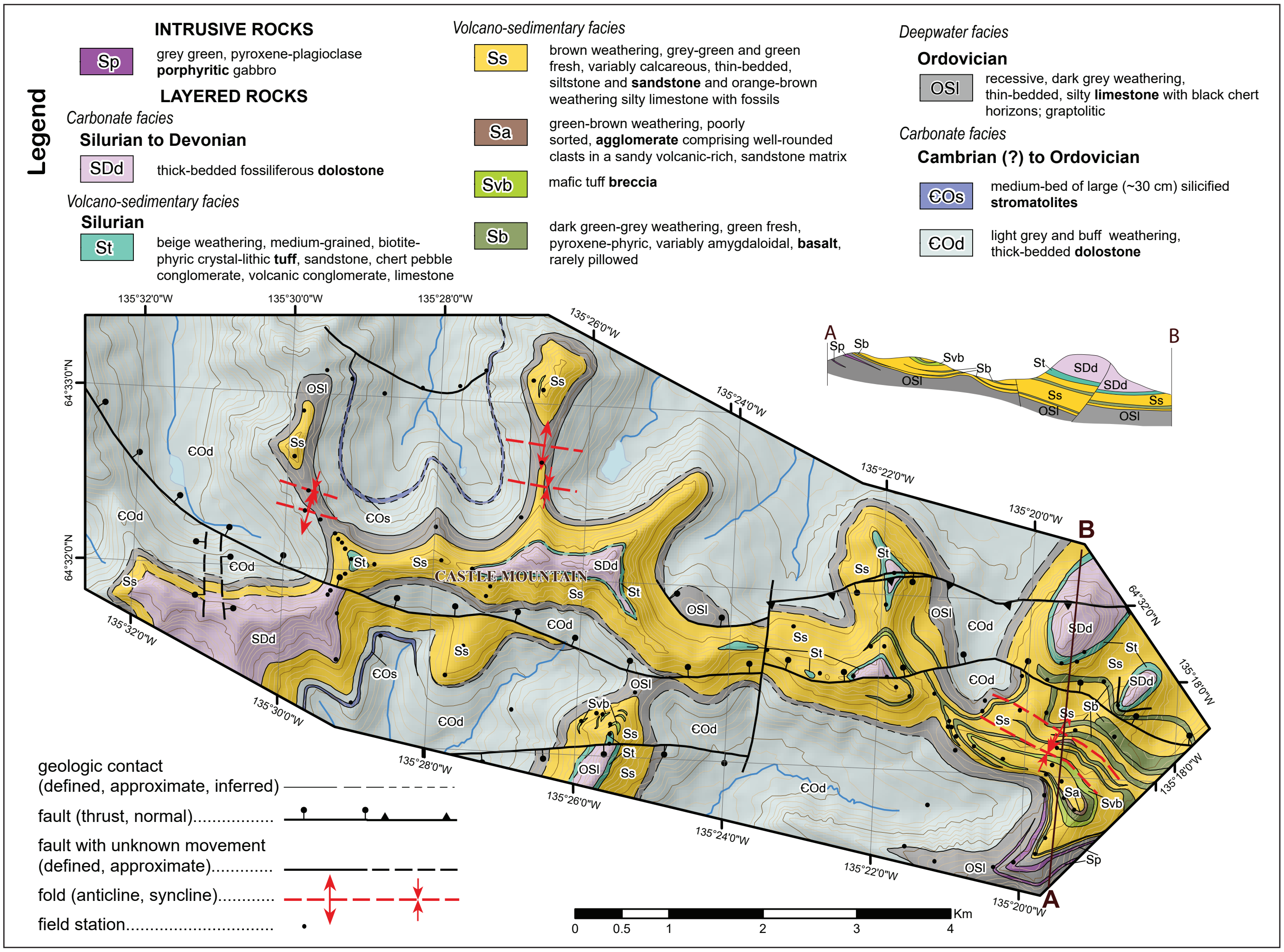

Figure 2. *Geologic map and cross section of the Castle Mountain area.*

Limestone–OSl

Dark, soil-rich scree slopes form a recessive band above the dolostone on all sides of Castle Mountain. Outcrop exposures of this unit comprise dark grey and light grey, recessive weathering, thin and medium-bedded, dark grey, silty limestone with black chert horizons (Fig. 3c). The chert forms continuous beds in some localities and elongate nodules in others. Graptolites are common both in the silty limestone and preserved on top of chert horizons (Fig. 3d). Locally, slump-folds on the ten-centimetre scale occur in the limestone layers (Fig. 3e).

Thickness for this unit ranges from zero to sixty metres throughout most of the map area. In the very southeastern part of the map, the limestone attains thicknesses of up to 200 m but in this area, several sills over-thicken the unit, exaggerating its true thickness (Figs. 4 and 7). Both upper and lower contacts are conformable and abrupt. The occurrence of graptolites of the form *Monograptus* and *Diplograptus*, collected from this unit in the southeastern edge of the map area, suggests an early Silurian age for the limestone (Blodgett, R., pers. comm.; Fig. 3f).

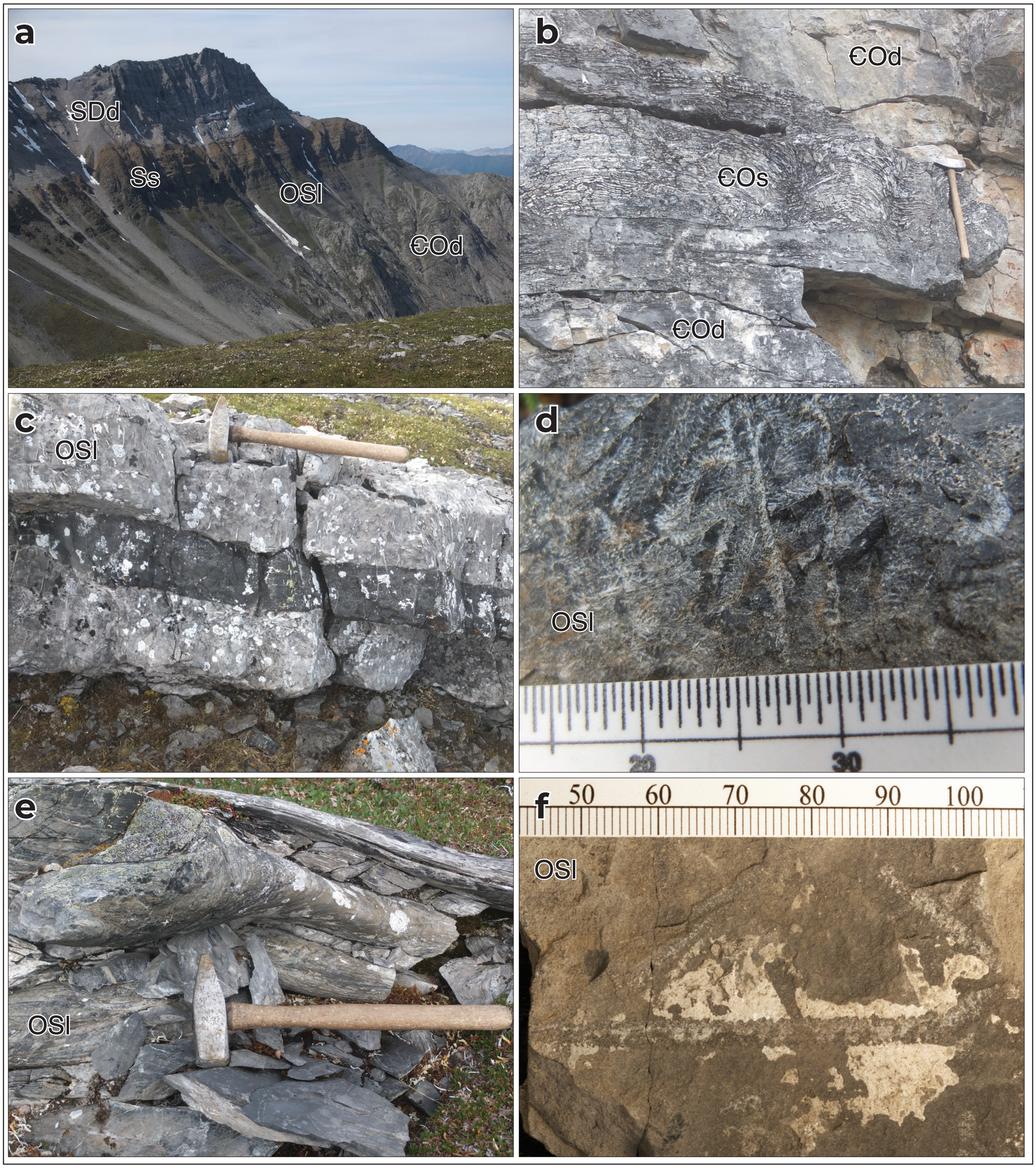

Figure 3. *Photographs of rock exposures from the lower dolostone unit (*ЄOd*) and the limestone unit (*Sl*).* ***(a)*** *Buff weathering dolostone typical of the* ЄOd *unit comprise the band of rock in the lower right hand corner of the map. Above this dark weathering rocks are unit* Ss*. Grey weathering band forming the top of the ridge is upper dolostone unit (*SDd*). Photograph was taken from 476549E 7156920N looking southward.* ***(b)*** *Silicified stromatolites within thick-bedded dolostone (*ЄOs*) in the western part of the map area (476798E, 7155126N).* ***(c)*** *Thin-bedded silty limestone interbedded with black chert of the* Sl *unit (476393E, 7157064N).* ***(d)*** *Graptolites preserved on the top of the bed of black chert from the* Sl *unit (476403E, 7158654N).* ***(e)*** *Slump folds within the silty limestone layers of the* Sl *unit (476393E, 7157064N).* ***(f)*** *Early Silurian graptolites from 484158 E 7153799N.*

Volcano-Sedimentary Succession–Ss, St (west Castle Mnt)–section with minor volcanic rocks

Dark weathering, well-bedded, fine to coarse clastic sedimentary rocks form a distinct, relatively flat lying band below the castellated peak of Castle Mountain and adjoining ridges in the western half of the map area (Fig. 3a). Within this unit, a lower section, dominated by dark green-brown weathering clastic rocks, comprises approximately half the unit thickness and occurs directly below an upper section of orange-brown weathering calcareous rocks capped by quartz-rich sandstone, limestone and tuff (Fig. 4).

The lower part of Ss lies directly on the lower silty limestone unit where it dominantly comprises dark greenish-brown weathering, thin to medium-bedded, calcareous, grey siltstone and calcareous, fossiliferous sandstone. Light green and brown weathering, fossiliferous, calcareous siltstone is interbedded with buff-grey limestone with rare interbeds of cross-bedded calcareous sandstone (Fig. 5a). Medium-beds of dark weathering sandstone contain approximately 5% volcanic clasts. These beds weather into distinct lens shaped cobbles and are a minor part of the lower section. Also in minor proportion, fine-grained lithic sandstone, fossiliferous sandstone, siltstone and conglomerate with carbonate clasts and shell fragments, occur in this section in order of decreasing abundance. North of Castle Mountain, boulders of volcanic breccia comprise angular cobble-size clasts of volcanic rock in a sandy matrix, are anomalous within the well-bedded clastic succession. Gradationally overlying this lower succession, a distinctly orange-brown weathering, medium-bedded, highly fossiliferous, grey silty and sandy limestone occupies most of the upper half of unit Ss (Fig. 4). Typical fossils in this part of the section include ammonites, trilobites, crinoids and bi-valves (Fig. 5b,c). A single thick bed of bright orange weathering limestone occurs near the top of the orange-brown weathering rocks.

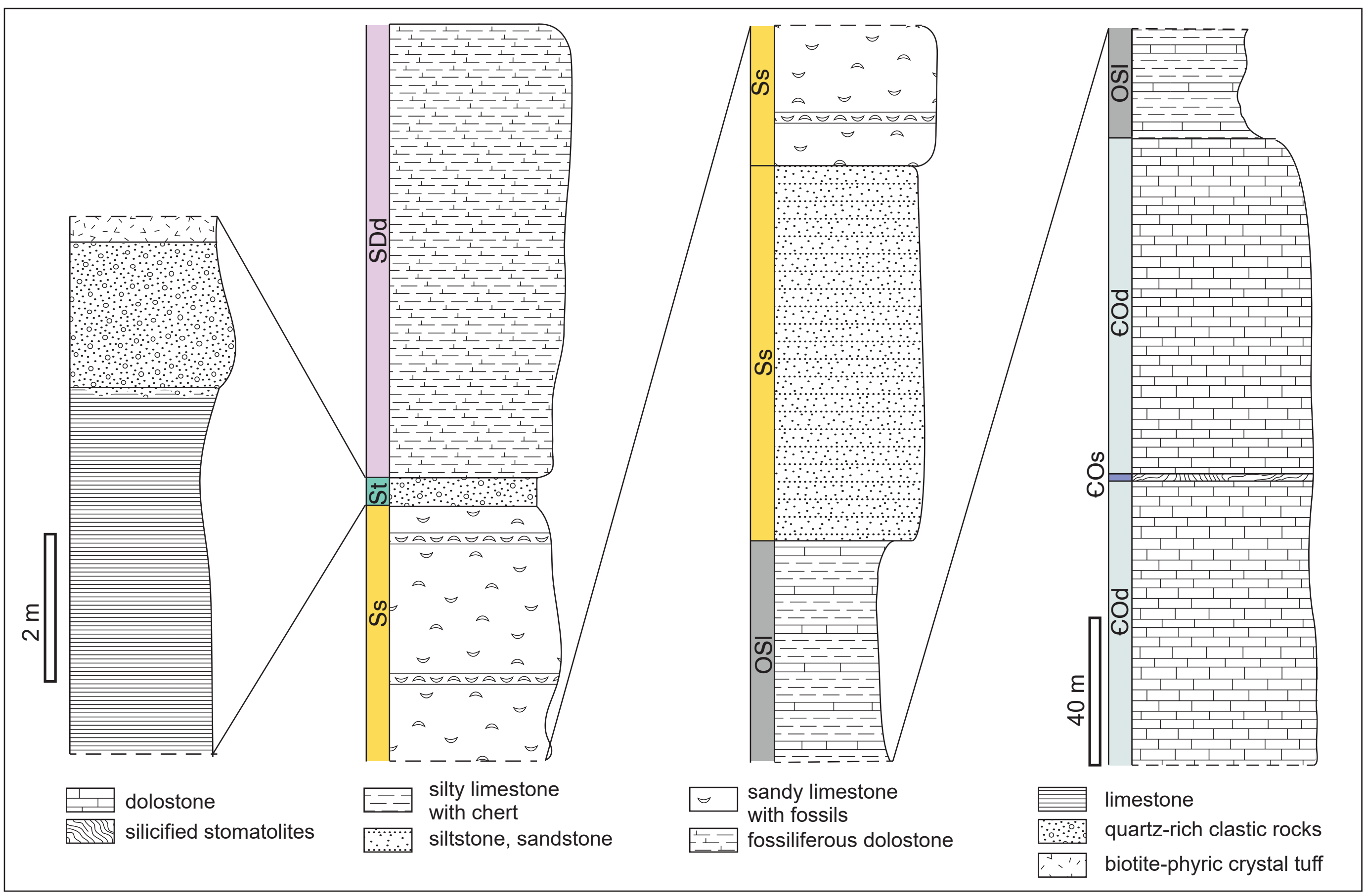

Figure 4. *Schematic stratigraphy from the western part of the Castle Mountain area.*

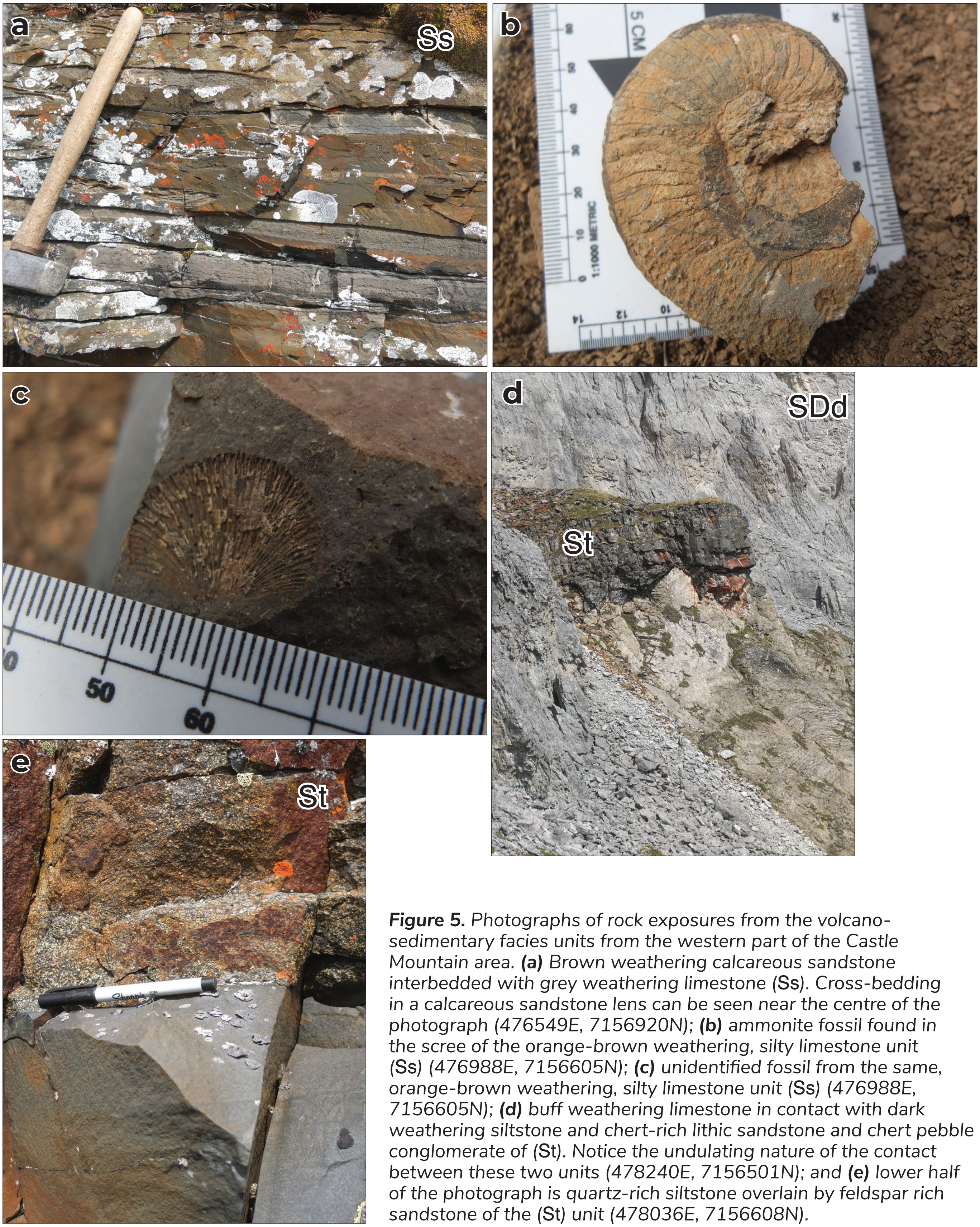

__Figure 5.__ Photographs of rock exposures from the volcano-sedimentary facies units from the western part of the Castle Mountain area. __(a)__ Brown weathering calcareous sandstone interbedded with grey weathering limestone (Ss). Cross-bedding in a calcareous sandstone lens can be seen near the centre of the photograph (476549E, 7156920N); __(b)__ ammonite fossil found in the scree of the orange-brown weathering, silty limestone unit (Ss) (476988E, 7156605N); __(c)__ unidentified fossil from the same, orange-brown weathering, silty limestone unit (Ss) (476988E, 7156605N); __(d)__ buff weathering limestone in contact with dark weathering siltstone and chert-rich lithic sandstone and chert pebble conglomerate of (St). Notice the undulating nature of the contact between these two units (478240E, 7156501N); and __(e)__ lower half of the photograph is quartz-rich siltstone overlain by feldspar rich sandstone of the (St) unit (478036E, 7156608N).

An approximately ten metre thick section of limestone, greywacke and tuff caps the upper part of the Ss section, and is identified separately on the geologic map (St; Figs. 2 and 4). This unit has been included in the volcano-sedimentary formation because it comprises these two rock types but is distinct from the underlying strata. At the base of this section, a reddish and buff weathering, fossiliferous limestone commonly has dark grey, wavy laminations throughout. The top surface of the limestone is irregular and undulating, and the troughs filled with grey-brown weathering chert-pebble conglomerate or quartz-rich siltstone (Fig. 5d). The conglomerate grades upwards into a quartz-rich greywacke, into a black weathering and fresh tuffaceous siltstone that is highly magnetic, into a coarse-grained, feldspar-rich sandstone with a dark, silty matrix (Fig. 5e). Above this, more chert pebble conglomerate and greywacke are common. The top of this sub-unit everywhere within the map area is a beige weathering and fresh, medium-grained, biotite-phyric, crystal-lithic tuff.

The thickness of this entire succession in the western part of the map area, including both Ss and St is approximately 200–250 m. It sits abruptly and conformably above the limestone unit (OSl). Its contact with the overlying dolostone is also conformable and abrupt. The calcareous clastic section makes up almost the entire thickness because the upper section contains approximately 5 m of limestone, 2 m of quartz-rich siltstone, sandstone and conglomerate and 30 cm or less of crystal-lithic tuff (Fig. 4).

Volcano-Sedimentary Succession–Ss, St, Sb, Sa, Svb **(east Castle Mnt)–section with abundant volcanic rocks**

The eastern part of the map contains at least three separate coherent mafic volcanic horizons and abundant volcaniclastic and tuffaceous rocks. In general, the volcanic component over the map area increases eastwards (Fig. 2). The more easily erodible nature of the volcanic rocks has created more recessive weathering than in the western part of the map and therefore many sections are covered. The following is a description derived from several different traverses through this unit and may not reflect the exact stratigraphy at any one location.

The base of the succession comprises a mixture of mafic to intermediate volcanic rocks interlayered with volcaniclastic and calcareous fine to coarse clastic rocks. The volcanic rocks include dark green-grey mafic tuff breccia (Svb), amygdaloidal, pyroxene-phyric basalt (Sb; forms pillows in some localities), bedded vitric tuff and a singular thin-bed of welded tuff. Green-grey weathering, thin-bedded volcaniclastic sandstone and siltstone, thinly interbedded with calcareous sandstone, mainly occurs above the volcanic rocks (Ss). This succession grades upwards into brown-grey weathering, thin-bedded, mildly calcareous sandstone interbedded with siltstone with occasional beds of fossiliferous sandstone (Ss). A second volcanic horizon comprises up to five metres of dark green-grey weathering volcaniclastic sandstone interbedded with siltstone (Ss) and capped by a five-metre thick amygdaloidal, pyroxene-phyric, basalt flow (Sb) that is locally overlain by mafic tuff breccia (Svb; Fig. 6a). Laterally this horizon comprises up to 40 m of coherent dark green-grey basalt (Sb) interlayered with both mafic tuff breccia (Svb) and green-weathering agglomerate (Sa). Above the basalt is an approximately one-metre thick bed of volcanic breccia with minor limestone cobbles that eastwards is replaced by orange-grey weathering, thick-bedded, grey, quartz-phyric, welded crystal tuff. Grey-brown weathering, thin-bedded, calcareous sandstone, interbedded with calcareous, fossiliferous siltstone, occurs above the welded tuff and breccia (Ss). An upper (third) volcanic horizon, mapped in the eastern part of the map, comprises two coherent basaltic to andesitic flows (Sb) separated by several metres of mafic tuff breccia (Svb; Fig. 6b). The flows and breccia reach a maximum thickness of thirty metres and taper to less than ten metres over one kilometre. Dark brown and green weathering, sandy, matrix-supported conglomerate, dominated by well-rounded cobbles of mafic to intermediate volcanic rock, occur stratigraphically above this volcanic horizon. Farther west, well-bedded, dark grey, thin to medium-bedded, lithic siltstone, interbedded with light purple-grey weathering, coarse-grained fossil-rich sandstone, lies above the uppermost volcanic horizon and may be a lateral equivalent to the conglomerate (Ss; Fig. 6c).

Figure 6. *Photographs of rock exposures of the volcano-sedimentary facies from the eastern part of the Castle Mountain area.* ***(a)*** *Pyroxene-phyric basalt flow comprising a lower, coherent section overlain by brecciated basalt (*Sb*; 484949E, 7155078N).* ***(b)*** *Weathered surface of mafic tuff breccia (*Svb*; 484341E, 7154941N).* ***(c)*** *Purplish grey weathering coarse-grained, fossil-rich sandstone interbedded with dark grey weathering siltstone (*Ss*; 479575E, 7155013N).* ***(d)*** *Ridge on the right side of the photograph comprises a lower section of purple-maroon weathering volcanic conglomerate overlain by quartz-rich clastic rocks, limestone and biotite-phyric tuff (*St*) and an upper section comprising light grey weathering dolostone (*SDd*). Photograph taken at location 484975E 7155419N looking northwest.* ***(e)*** *Volcanic conglomerate comprising well-rounded clasts in a calcareous, sandy matrix of the* St *unit (484354E, 7155845N).* ***(f)*** *Red weathering, thin-bedded sandstone of the* St *unit (484975E, 7155419N).*

Similar to the western part of the map the top of the volcano-sedimentary succession comprises quartz-rich clastic rocks, conglomerate and tuff (St). Unlike in the west, this unit is much thicker in the east where it attains thicknesses of up to fifty metres (Figs. 6d and 7). The base of this stratigraphy comprises grey weathering limestone overlain by maroon-purple weathering volcanic conglomerate. The conglomerate has well-rounded clasts of intermediate and mafic volcanic rocks in a calcareous, sandy matrix (Fig. 6e). Shell fragments and crinoids are common within more sandy lenses of the conglomerate. Farther up section, thin and medium beds of red weathering, sandstone and pebble conglomerate lie above the volcanic conglomerate (Fig. 6f). Dark grey weathering, quartz-rich lithic sandstone, highly magnetic siltstone, and chert pebble conglomerate sit between the red weathering clastic rocks and a beige, highly fossiliferous bed of limestone. Above the limestone, a bed of biotite-phyric crystal lithic tuff caps the entire volcano-sedimentary succession.

Fossiliferous dolostone (SDd)

Light grey weathering, thick-bedded to massive, fossiliferous dolostone cap the castellated peaks of Castle Mountain and adjoining ridges. Thick beds taper and pinch out in some areas (Fig. 8a). Stromatolites, corals and many unidentifiable fossils and fossil fragments are common within this dolostone (8b). Locally, patchy, laminated dolostone occurs between coral-rich sections (Fig. 8c).

The dolostone is in direct, conformable contact with the underlying crystal-lithic tuff. The upper contact is not exposed within the map area, allowing a minimum thickness estimate for this unit of 150 m.

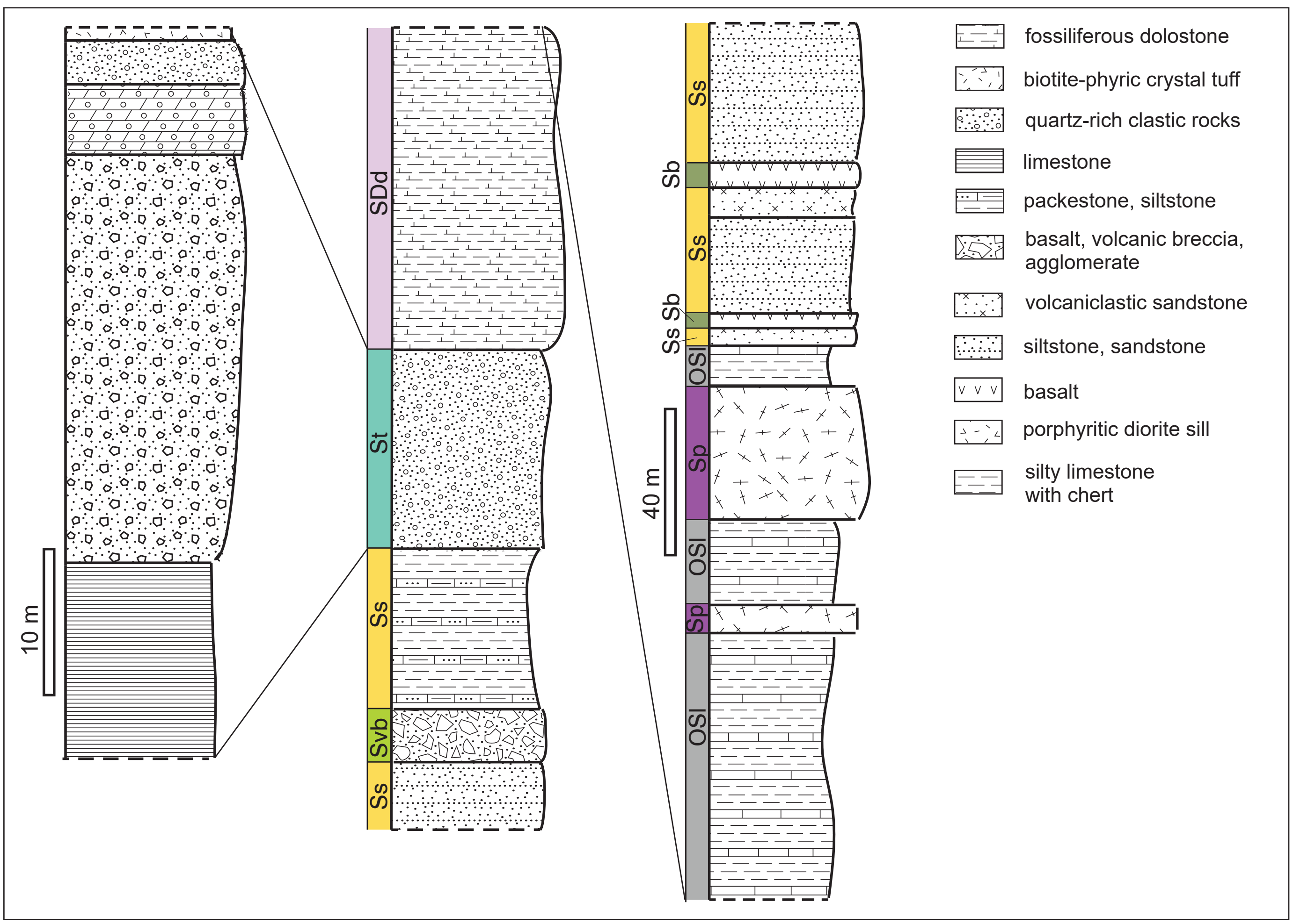

Figure 7. *Schematic stratigraphy from the eastern part of the Castle Mountain area.*

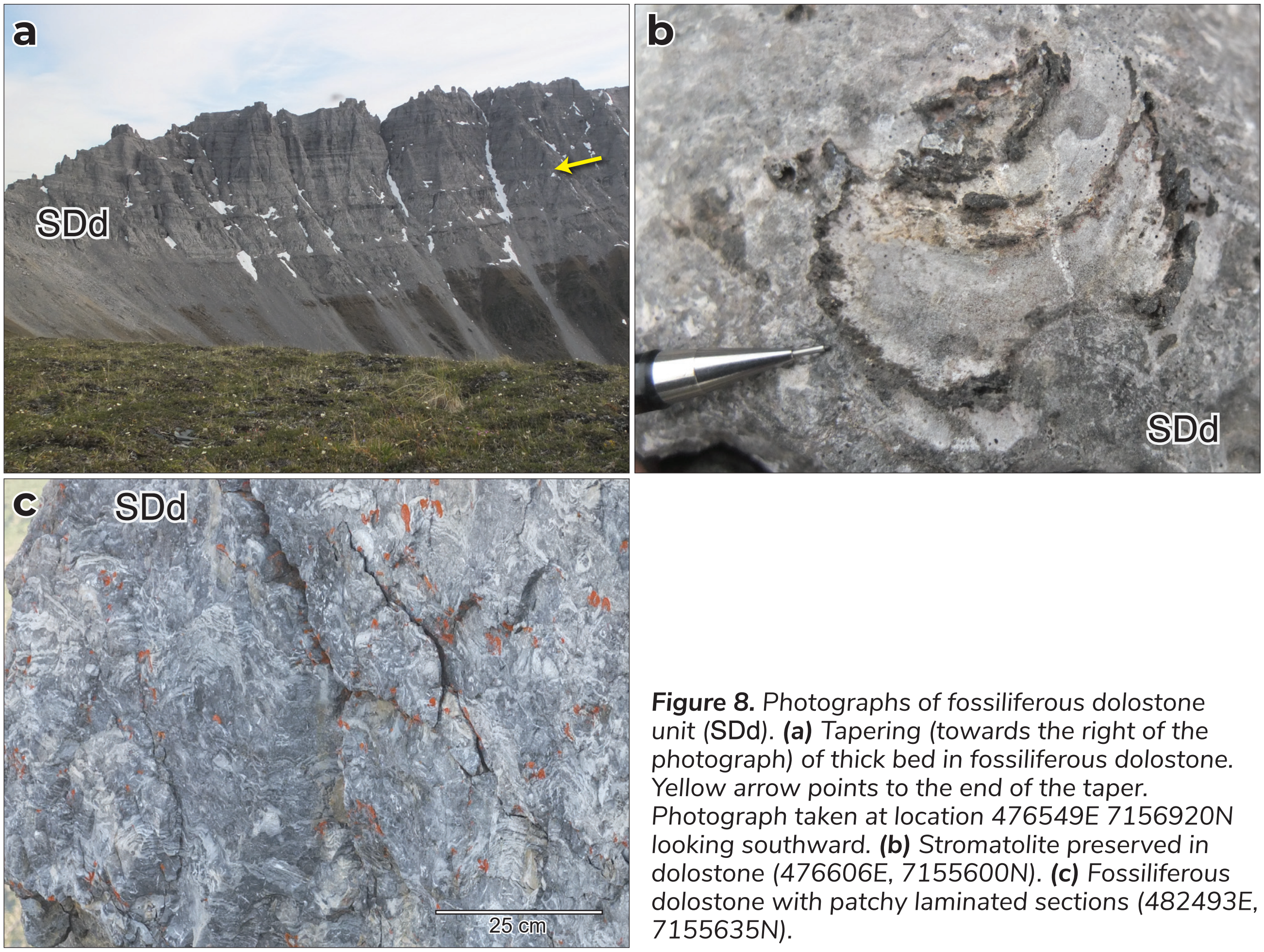

Figure 8. *Photographs of fossiliferous dolostone unit (SDd).* ***(a)*** *Tapering (towards the right of the photograph) of thick bed in fossiliferous dolostone. Yellow arrow points to the end of the taper. Photograph taken at location 476549E 7156920N looking southward.* ***(b)*** *Stromatolite preserved in dolostone (476606E, 7155600N).* ***(c)*** *Fossiliferous dolostone with patchy laminated sections (482493E, 7155635N).*

Structure

Strata across the Castle Mountain area are relatively flat lying. Small but systematic changes in dip of beds characterize east-west oriented open folds (Fig. 2). Steeply dipping normal faults oriented both north-south and east-west have measureable offsets that range from 60 to 100 m. Alteration and brittle deformation of strata delineate faults with unknown movement but offset along these are structures appear to be minor.

Discussion

Depositional environments of carbonate and basin facies

Deposition of the older dolostone (ЄOd) in shallow water, along an epeiric or detached platform, is consistent with the lack of siliciclastic sediment, thick-bedded nature of the carbonate rocks, and the presence of stromatolites (Tucker, 2009). A shift from shallow to deeper water is suggested by deposition of overlying thin-bedded graptolite-bearing, silty limestone (OSl). The synsedimentary folding within the deeper water unit suggests deposition on a slope in an intermediate environment between a shelf and a basin (Tucker, 2009).

Following the transgressive period, the Castle Mountain area must have been situated proximal to a sediment source as it subsequently filled with well-bedded clastic strata comprising carbonate, arkosic and volcanic detritus as well as fossils (Ss). For example, the strata at the top of the St unit contains chert-rich sandstone and conglomerate, as well as conglomerate with well-rounded volcanic clasts. Cross-bedding and silty limestone containing ammonites, trilobites and crinoids suggest deposition in relatively shallow water close to shore (Tucker, 2009), and are evidence that the Castle Mountain area was a catchment for sediment sourcing eroding chert, carbonate and volcanic rocks.

A return to a shallow water environment with limited clastic input occurs immediately after the deposition of a felsic, crystal-lithic tuff (top-most unit in St), as indicated by the build-up of carbonate rocks (SDd). The presence of coral fossils with very patchy laminated sections is interpreted to represent infilling of carbonate sediment between reef frame builders that were bound together during deposition suggesting they may be boundstone (Tucker, 2009). The thick-bedded nature of the dolostone in combination with the tapering of individual thick beds suggests local patch reef buildups were common.

Volcanism

Volcanism appears to be simultaneous with calcareous, clastic rock (Ss) deposition as flows are interbedded with the base of these strata in the eastern part of the map area. In addition, the basal clastic rock package contains many mafic volcanic clasts, which are interpreted to be sourced from nearby, eroding volcanic piles linked to the same magmatic episode as the flows and tuffs that are deposited within the clastic rock succession. Crystal-lithic tuff is deposited across the entire map area and marks the last episode of volcanism before carbonate build-up resumes.

Tectonic implications

Abbott (1997), who documented rift-related volcanic rocks overlying shale containing Early Silurian graptolites in the Upper Hart River area, reports one of the few notable occurrences of Silurian volcanic rocks in the northern Cordillera. Other workers attribute lower Paleozoic volcanism within the North American continental margin to rift-related extension but do not specifically recognize Silurian volcanic rocks (e.g., Cecile, 1982).

At Castle Mountain, extension related faulting resulting in local tectonic subsidence would drown parts of the carbonate platform and explain the deposition of deeper water facies on top of dolostone. Decompressional melting due to lithospheric thinning associated with crustal extension may have resulted in underplating of igneous rocks and local thermal uplift. This model is one way of explaining the local exposure and subsequent erosion of chert, carbonate and volcanic rocks. Crustal breaks from uplift induced normal faulting or faulting related to crustal extension would facilitate the rise of magmas through the upper crust. Regional, thermal subsidence following volcanism is consistent with a return to carbonate facies at Castle Mountain and surrounding areas.

Future work

Detailed work east of the mapped area is essential for full characterization of the volcanic rocks exposed here. This summer's fieldwork captured the details of the stratigraphy and provided many samples for fossil, geochemical and geochronological analyses. Due to time constraints, it did not include areas where the volcanic rocks reach maximum thickness. East of the map area, it appears that the volcanic rocks overwhelm the section and become much thicker and future work will involve geological mapping in these areas.

Acknowledgements

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