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Preliminary report on the Triassic and Jurassic stratigraphy and paleontology of the Sinwa and Takwahoni formations near Lisadele Lake, Tulsequah map area, northwestern British Columbia

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Abstract: A southwestern outlier of the Whitehorse basin strata in central Tulsequah map area (NTS 104 K/11) includes interbedded fossiliferous conglomerate, sandstone, siltstone, and mudstone of the Lower to Middle Jurassic Takwahoni Formation (Laberge Group) that unconformably overlies Upper Triassic limestone of the Sinwa Formation. The refined age and provenance of several episodes of coarse clastic input into the basin show that the character of the dominant clasts in the conglomerate changes upsection. Immediately above the unconformity, breccia and conglomerate contain sedimentary clasts derived from the Sinwa Formation. Clast dominance changes to volcanic near the base of the section, plutonic (in Pliensbachian-Toarcian strata), metamorphic (in uppermost Toarcian rocks), and finally, after an interval of fine-grained sedimentation, to chert in the Middle Jurassic strata of Early Bajocian age. The uppermost chert-pebble conglomerate and the underlying black mudstone beds are tentatively placed in the Bowser Lake Group.

Résumé : Un lambeau de strates du bassin de Whitehorse, situé au sud-ouest de celui-ci dans la partie centrale de la région cartographique de Tulsequah (SNRC 104K/11), comprend une succession fossilifère de conglomérats, de grès, de siltstones et de mudstones interstratifiés appartenant à la Formation de Takwahoni (Groupe de Laberge) du Jurassique inférieur et moyen, qui surmonte en discordance des calcaires du Trias supérieur attribués à la Formation de Sinwa. Les âges mieux circonscrits de plusieurs épisodes d'apport de matériaux détritiques grossiers dans le bassin et la détermination de leur provenance sédimentaire indiquent un changement vers le haut du caractère des clastes dominants dans les conglomérats. Immédiatement au-dessus de la discordance, les brèches et les conglomérats renferment des clastes sédimentaires provenant de la Formation de Sinwa. La composition prédominante des clastes devient volcanique près de la base de la coupe, puis plutonique (dans les strates du Plienbachien-Toarcien) et ensuite métamorphique (dans les roches du Toarcien sommital). Enfin, après un intervalle témoignant d'une sédimentation de matériaux à grain fin, les clastes apparaissent surtout composés de chert dans les strates du Jurassique moyen datant du Bajocien précoce. Les conglomérats à cailloux de chert sommitaux et les couches sous-jacentes de mudstone sont attribués provisoirement au Groupe de Bowser Lake.

INTRODUCTION

In northwestern British Columbia, the Whitehorse Trough comprises Jurassic fine- to coarse-grained siliciclastic rocks of the Laberge Group, which extends from north-central British Columbia west and northwest to southwestern Yukon. Although the Whitehorse Trough is faulted along most of its margins, with the oceanic Cache Creek terrane to the northeast and volcanic arc-related Stikine terrane to the southwest, its depositional history is linked to the evolution of these adjacent terranes (Fig. 1) and, consequently, it has been well studied throughout its extent (e.g. Souther, 1971; Bultman, 1979; Thorstad and Gabrielse, 1986; Gordey et al., 1991; Hart et al., 1995; Mihalynuk et al., 1995a, b, 1999, 2004; Johannson et al., 1997; English et al., 2003; and references therein).

The Laberge Group also occurs in scattered outliers southwest of the main extent of the Whitehorse Trough. One of the best exposed and most complete stratigraphic sections of the Takwahoni Formation of the Laberge Group occurs in the vicinity of Lisadele Lake in the central part of the Tulsequah map area (Mihalynuk et al., 1995a, b). At this locality, the sequence rests with angular unconformity on the Sinwa Formation and includes five conglomeratic units the ages of which are now constrained by over 40 ammonite collections. This report summarizes the progress of new stratigraphic and paleontological studies. Additional work is underway aimed at constraining the age of detrital zircon grains in sandstone matrices and of some granitoid clasts in conglomerate units, the ages of which are well constrained biochronologically.

STRATIGRAPHY

Upper Triassic Sinwa Formation

The Sinwa Formation is one of the most distinctive lithological units in northwestern British Columbia (Souther, 1971). It consists of carbonate-rich rocks, including major reef build-ups, extending from the Tulsequah map area in the south (the type locality; Souther (1971)) northward to the Tagish Lake area and into the Yukon where patch reefs occur (Reid and Tempelman-Kluit, 1987). In the study area, the limestone forms the base of the sequence and is about 30 m thick. The contact between the Sinwa Formation and the Lower Jurassic conglomerate and sandstone of the Laberge Group is an erosional unconformity (Fig. 2, 3).

The Sinwa Formation is a fossiliferous, thick-bedded, massive, light grey limestone, with a distinctive light pink weathering colour. Iron oxide cement is present in most samples and it is abundant locally. Preliminary microscopic study of the limestone indicates that it is a packed biomicrite (classification of Folk (1959)) with allochems that are mainly bivalve, gastropod, and brachiopod shell fragments. Crinoids, corals, and algae are also present (Fig. 4a, b). These sedimentary rocks were probably deposited in a generally low-energy environment, below wave base and close to a source of reef detritus. Coral alignment indicates local paleocurrents were directed to the northeast (Fig. 5).

The precise age of the uppermost beds of the Sinwa Formation is important in assessing the duration of the hiatus between depositions of the formation and overlying Lower Jurassic strata. One constraint derives from the Early and Middle Norian age determined for ammonites collected from the limestone a few metres below the unconformity. Samples collected for microfossils from the uppermost limestone in the Sinwa Formation and from conglomerate clasts within the basal Laberge Group yielded a nondiagnostic ichthyolith and echinoderm fauna.

Lower and Middle Jurassic succession

More than 3000 m of conglomerate, sandstone, siltstone, and mudstone constitute the Lower to Middle Jurassic Takwahoni Formation of the Laberge Group in the Lisadele Lake area. Results of ongoing petrographic studies of sandstone samples from these strata will be reported elsewhere. Five conglomerate units are recognized from the Jurassic succession in the Lisadele Lake area (Fig. 6, 7a–e, 8).

Conglomerate unit I

The lowermost 5 m of the Takwahoni Formation consists of poorly sorted, matrix-supported limestone-pebble to cobble breccia and conglomerate (Fig. 6). The matrix consists of reddish-brown-weathering sand and siltstone, whereas the subangular to angular clasts weather a distinctive white to light grey (Fig. 7a). They seem to be in situ intraclasts with an entirely intrabasinal origin. The age of the lowest conglomerate is poorly constrained. It occurs conformably below conglomerate unit II and is tentatively considered to be of probable Sinemurian age by analogy with the succession exposed in the Atlin Lake area (Johannson et al., 1997).

Conglomerate unit II

Within the Lisadele Lake area, the thickness of this unit varies between 100 m and 160 m (Fig. 6). The channellized conglomerate units are white-grey weathering, moderately to well sorted, and contain dominantly volcanic clasts that are subrounded to rounded (Fig. 7b). Some of the conglomeratic beds contain yellow-weathering, highly oxidized clasts. Bioclastic coarse-grained sandstone, greywacke, siltstone, and mudstone are the other components of this unit. Clasts are composed of intermediate to felsic volcanic rocks, dominated by dark grey- and green-weathering feldspar porphyries. Biochronological age control has been difficult to obtain, but Mihalynuk et al. (1999) reported a Lower Pliensbachian *Metaderoceras* from just above the unit.

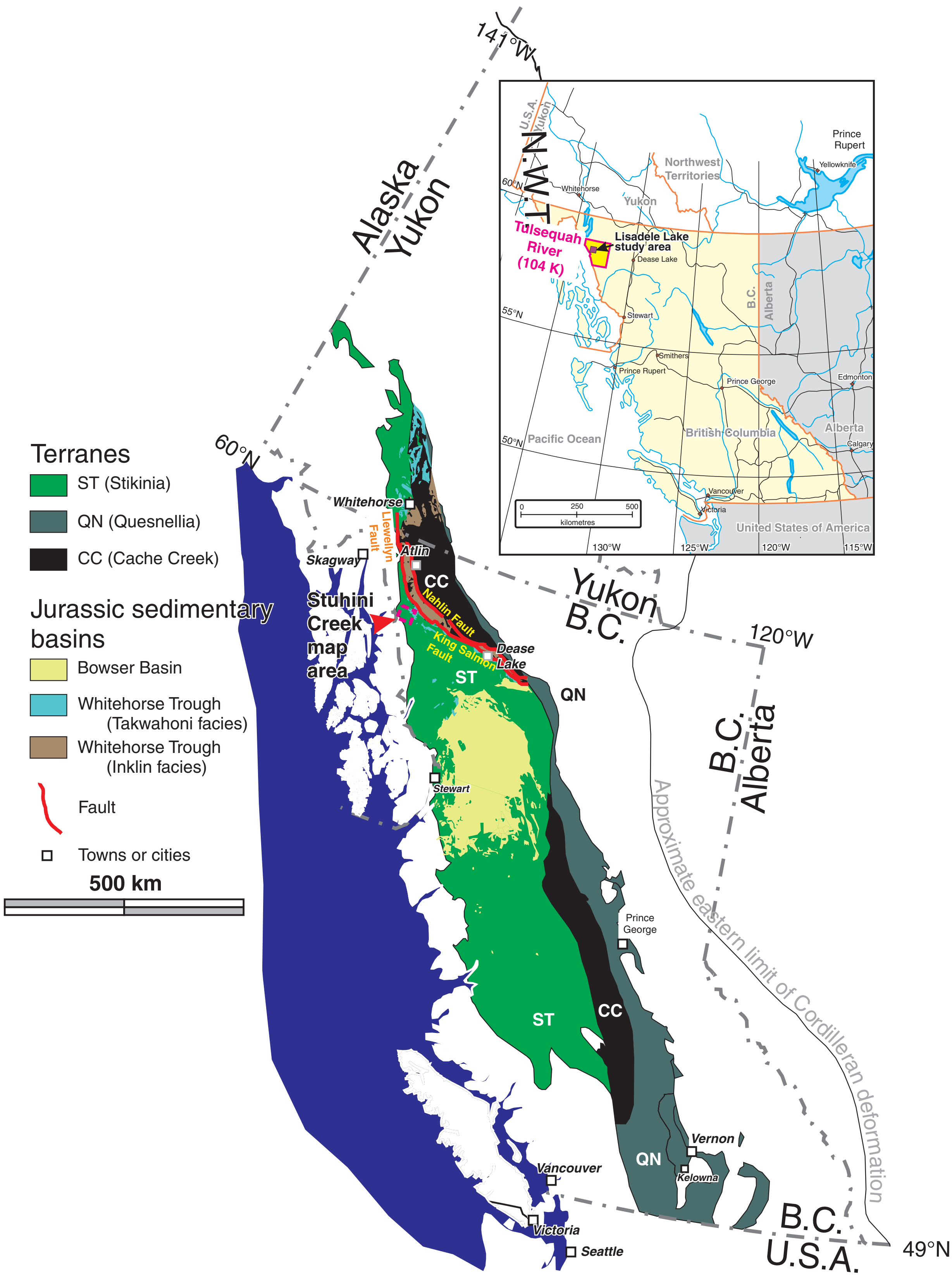

Figure 1. Terrane map (*modified from* Wheeler and McFeeley, 1991) showing the distribution of Inklin and Takwahoni facies of Laberge Group in Whitehorse Trough and bounding Nahlin, King Salmon, and Llewellyn faults. Inset location map shows the Tulsequah map area (NTS 104 K) and the Stuhini Creek 1:50 000 scale quadrangle (NTS 104 K/11) within which Lisadele Lake is located.

Figure 2. Lower Jurassic conglomerate and breccia (conglomerate unit I) resting unconformably on Upper Triassic limestone of the Sinwa Formation. The dashed line indicates the approximate position of the erosional unconformity. Hammer for scale is 25 cm. View is to the northwest.

Conglomerate unit III

Unit III is the thickest conglomerate unit (approximately 1200 m thick) and is dominated by plutonic, pebble- to boulder-sized plutonic clasts. The conglomerate units are poorly sorted, but the large clasts show high sphericity; normal and locally reversed grading is evident. Common clast types include leucogranite, diorite, monzonite, and quartz monzonite. Intermediate to felsic volcanic rocks are minor components and sedimentary clasts, possibly derived from the Sinwa Formation, are rare. Thin-bedded sandstone layers contain locally abundant, fragmented plant fossils.

The age of unit III is constrained by 12 ammonite collections, distributed fairly evenly from 250 m to 1350 m above the base of the section (Fig. 6). The lowest locality is a few metres below the base of unit III. The five localities interbedded with the lower part of conglomerate unit III yield typical Upper Late Pliensbachian ammonites belonging to the genera *Fanninoceras*, *Arieticeras*, *Fuciniceras*, *Reynesoceras*, and *Fontanelliceras*. The upper seven localities within unit III (Fig. 6) yield Lower Early and Middle Toarcian species of the genera *Cleviceras*, *Harpoceras*, *Dactylioceras*, *Leukadiella*, *Hildaites*, and *Phymatoceras*.

Conglomerate unit IV

Conglomerate in unit IV is about 200 m thick and contains abundant metamorphic rock clasts (Fig. 8). The conglomerate beds within unit IV are less dominant than in unit III, but none-the-less can reach thicknesses of about 30 m. They contain pebble- to cobble-sized clasts that are white or light to dark grey and set in a dark matrix that is locally orange to brown-orange (Fig. 7d). Clasts are dominated by metamorphic, and to a lesser extent, plutonic rocks. The clasts are poorly sorted and well rounded with local current-generated imbrications, suggesting northeast-directed paleocurrents.

The upper parts of unit IV display well sorted pebble to cobble conglomerate units interbedded with brown to light grey, coarse-grained sandstone. Microscopic studies of the metamorphic clasts are ongoing, but preliminary results indicate common occurrence of gneiss and quartz-rich schist.

Two ammonite localities bracket conglomerate unit IV; the lower locality is approximately 200 m below the base of the unit, and the upper one immediately overlies the upper contact. Both localities yield Upper Late Toarcian species of the genera *Phymatoceras* and *Podagrosites* (Fig. 8).

In contrast to the Lisadele Lake area, the youngest Early Jurassic conglomerate in the Atlin Lake area about 100 km to the north, are Pliensbachian; no Toarcian rocks are present (Johannson et al., 1997). Farther to the north in the Yukon, Toarcian conglomerate units have been recognized, but metamorphic clasts are rare and granitic clasts predominate (Dickie and Hein, 1995; Hart et al., 1995).

Conglomerate unit V

The upper approximately 1000 m of the Jurassic succession at Lisadele Lake is characterized by siltstone and mudstone, but the uppermost 5–10 m of the section consists of angular to subangular and well sorted, chert-granule to pebble conglomerate (unit V, Fig. 8). Ammonite collections from this interval include species of the genera *Sonninia*, *Dorsetensia*, and *Stephanoceras*, indicating an Early Bajocian age. Stephanoceratids from about 20 m below conglomerate unit V indicate an Early Bajocian age and Mihalynuk et al. (1999) reported Early Bajocian ammonites from within the conglomerate. Variegated chert clasts include black, dark green, white, red,

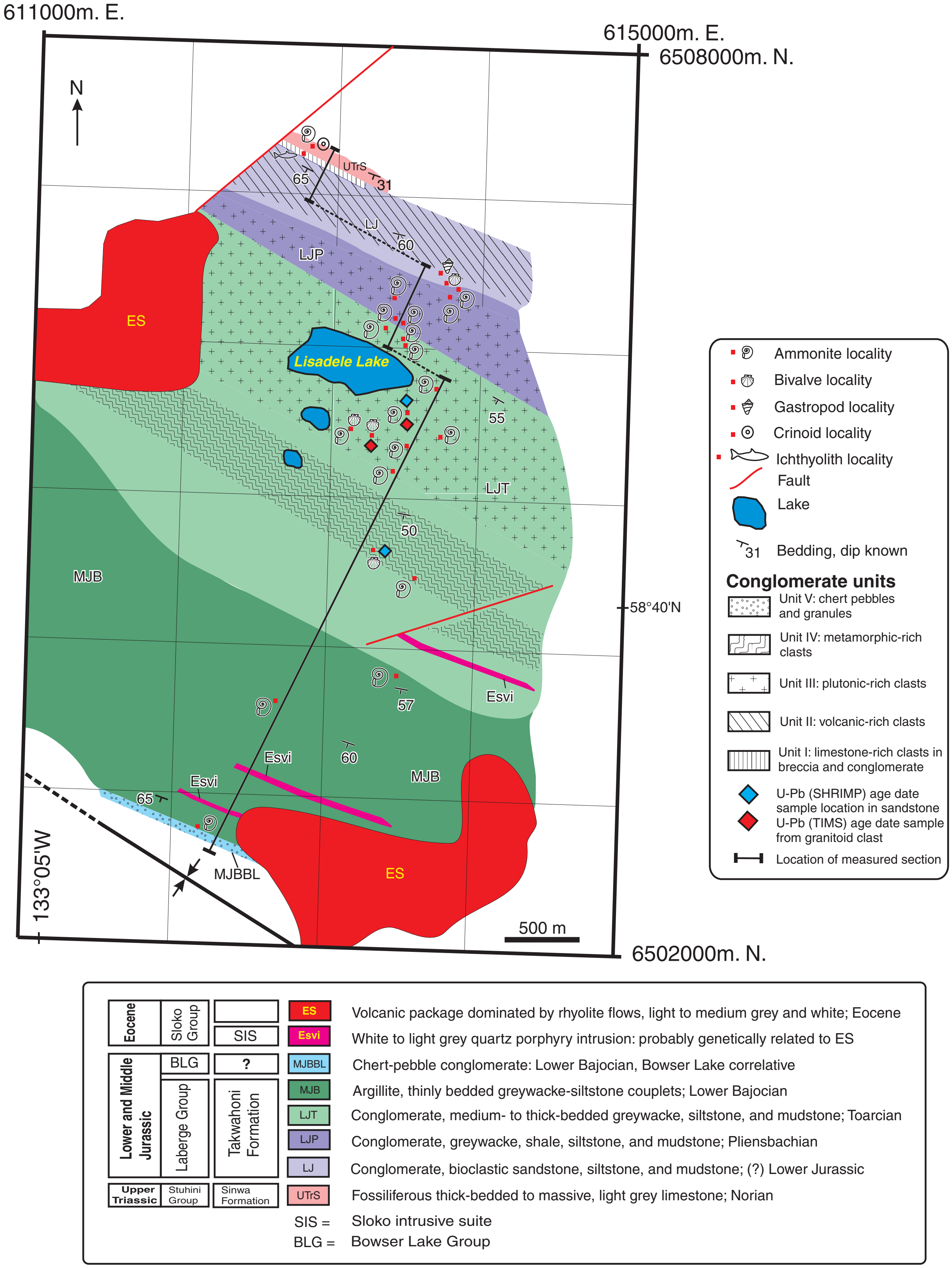

Figure 3. Geological map showing distribution of Laberge and Bowser Lake groups, conglomeratic units, fossil localities, and geochronology sample sites.

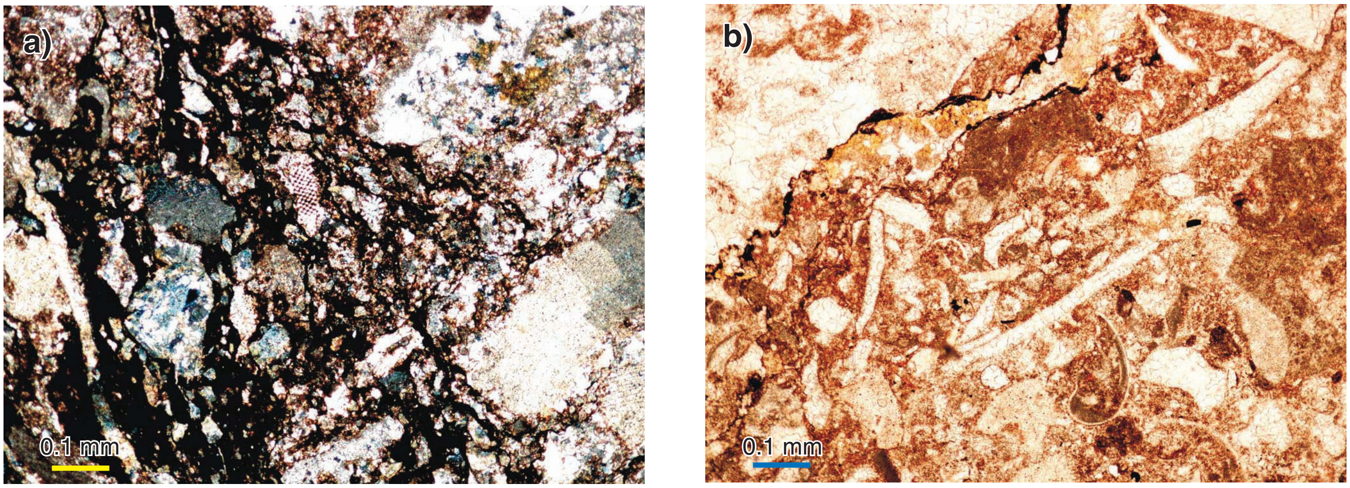

Figure 4. Photomicrographs of limestone from the Upper Triassic Sinwa Formation, Tulsequah map- area: **a)** packed biomicrite with algal and crinoidal fragments in a cement locally rich in iron oxide; **b)** packed biomicrite with bivalve shell fragments.

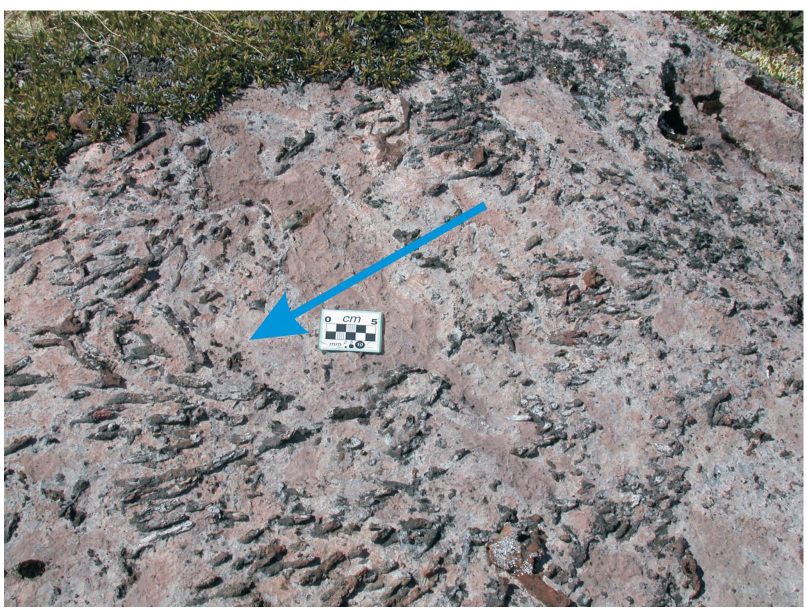

Figure 5. Corals in the Upper Triassic Sinwa Formation are aligned and indicate a local northeast-directed paleocurrent direction (the blue arrow). View is to the south.

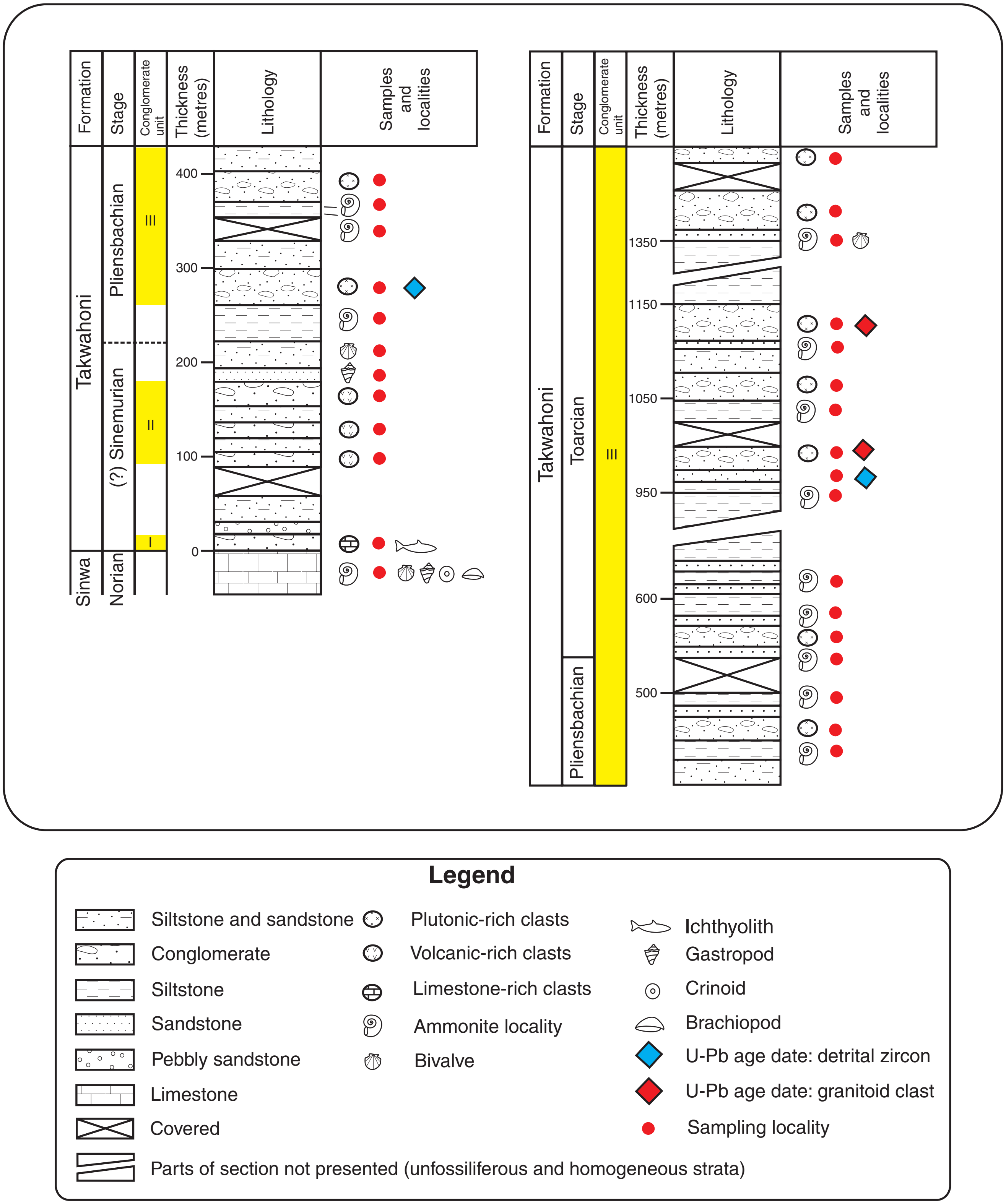

Figure 6. Upper Triassic and Lower Jurassic lithostratigraphy in the Lisadele Lake area. The yellow bars indicate the occurrence of each conglomerate unit as mentioned in the text.

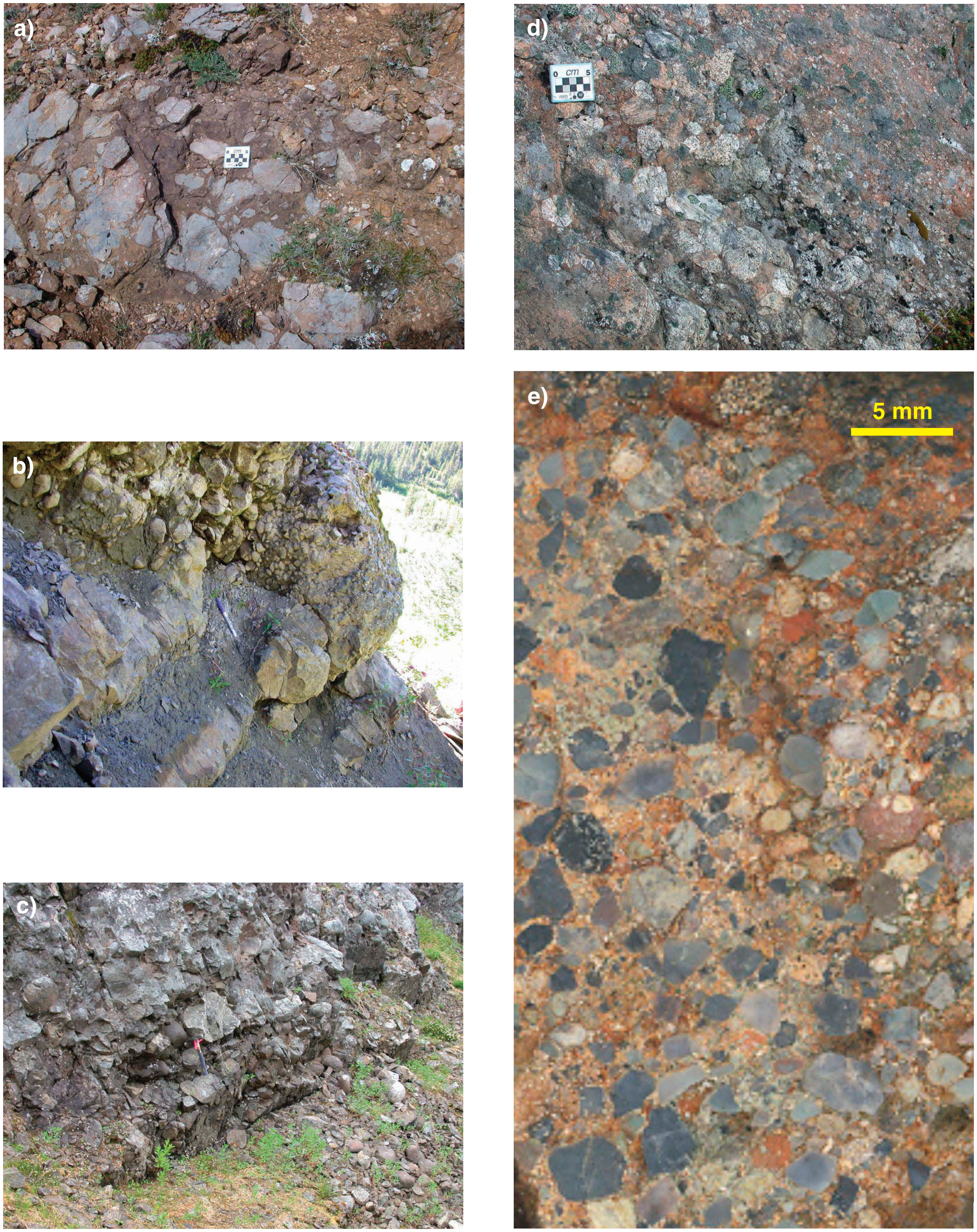

Figure 7. Conglomeratic units in the Tulsequah map area: **a)** unit I: Lower Jurassic (?Sinemurian) poorly sorted, subangular to angular limestone breccia; **b)** channellized Lower Jurassic conglomerate of unit II, dominated by volcanic rock clasts; pen for scale is 14 cm long; **c)** unit III: Pliensbachian-Toarcian well rounded cobble-boulder conglomerate, rich in plutonic clasts; hammer for scale is 25 cm; **d)** unit IV: Upper Toarcian conglomerate with dominant metamorphic and subordinate plutonic rock clasts within orange to brown-orange matrix; and **e)** unit V: Middle Jurassic (Bajocian) well sorted chert-granule conglomerate.

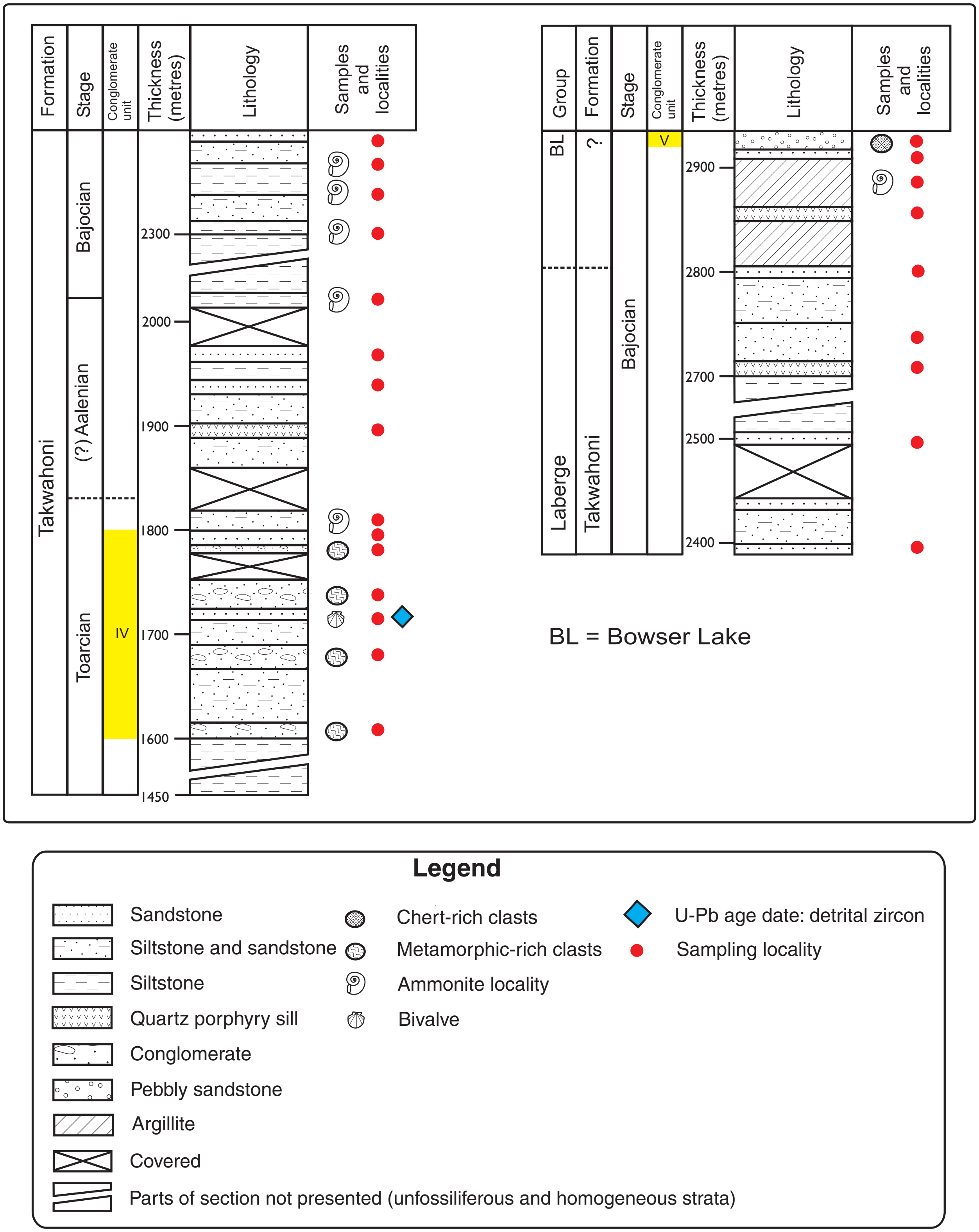

Figure 8. Lower and Middle Jurassic lithostratigraphy in the Lisadele Lake area. The yellow bars indicate the occurrence of each conglomerate unit as mentioned in the text.

and light to medium yellow varieties (Fig. 7e). Mihalynuk et al. (1999) report that some clasts within this unit contain radiolarians, ranging from Early Permian through Early Jurassic.

Conglomerate unit V is lithostratigraphically similar to conglomerate units of the Bowser Lake Group the locus of sedimentation of which is to the south in central Stikinia. The Bajocian age of Lisadele Lake conglomerate is slightly too old for it to be correlated directly with the Bowser Lake Group; however, the authors note that coarse clastic rocks of the same age (Early Bajocian) occur in the footwall of the King Salmon Fault in the Cry Lake map area (Gabrielse, 1998; Evenchick and Thorkelson, 2005). These rocks have been correlated with the Bowser Lake Group and consequently the present authors also tentatively include the conglomerate unit V described here and the underlying mudstone beds in this group. The implication is that the base of the Bowser Lake Group is diachronous, younging slightly from north to south (Fig. 8).

DISCUSSION

Conglomerate units in the Lisadele Lake area show a progressive systematic change in dominant clast type from sedimentary at the base, to volcanic, plutonic, and metamorphic clasts higher in the stratigraphy. This trend in clast composition suggests the sequential importance of platform carbonate rocks, arc volcanic and plutonic rocks, and the probable unroofing of a metamorphic core complex as source areas during basin evolution. A similar change in source areas with time has been documented in the Yukon, where coarse clastic sedimentary rocks were shed from the rapidly rising Triassic arc and deposited into the adjacent basin (Whitehorse Trough) during Early and Middle Jurassic, forming pebble-, cobble-, and boulder-conglomerate units (Dickie and Hein, 1995; Hart et al., 1995).

The sedimentation style changes from coarser grained in the Lower Jurassic to finer grained in the Middle Jurassic as conglomerate and sandstone give way to siltstone and claystone higher in the section. This probably reflects basin deepening associated with crustal flexure and/or eustatic sea-level changes (Dickie and Hein, 1995). The crustal flexure might reflect the onset of the final stages of the basin closure in the Whitehorse Trough. The appearance of chert-granule to pebble conglomerate (conglomerate unit V) at the highest stratigraphic level near the top of the succession reflects an important change in provenance as the oceanic sedimentary rocks of the Cache Creek terrane act as a primary source.

Geochronological studies of detrital zircon grains and plutonic clasts from Lower Jurassic strata are underway at the Geological Survey of Canada Geochronology Laboratory in Ottawa. These include analyses of zircon grains from three sandstone samples (Fig. 6, 8), and U-Pb zircon dating of two granitoid clasts (Fig. 6), all collected from biostratigraphically well constrained Upper Pliensbachian and Toarcian strata. The determination of their age and provenance will contribute to the understanding of a significant period of regional tectonism in northwestern British Columbia.

CONCLUSIONS

Ammonite biochronology constrains Takwahoni Formation and probable Bowser Lake Group strata in the Lisadele Lake area to an age range between Pliensbachian and Early Bajocian, with all stages except for the Aalenian represented. Further study of the Takwahoni Formation will reveal information about the tectonic and basin history of the Whitehorse Trough during the Jurassic. The Lisadele Lake succession contains conglomerate units that indicate five distinct depositional intervals during the Early and Middle Jurassic. Predominant provenance of clast types change upsection from sedimentary to volcanic, plutonic, metamorphic, and, finally, chert-rich sources. The appearance of the Early Lower Bajocian chert-pebble conglomerate is possibly related to the obduction of the Cache Creek terrane, followed by derivation and influx of chert-rich detritus into the Whitehorse Trough before the final stage of basin closure.

Stratigraphic records of the Whitehorse Trough in Yukon, Atlin, and the Tulsequah areas indicate differences in the rock type and timing of the events during periods of the depositional history of the basin. This situation is common in zones of oblique convergence, such as that interpreted for the Jurassic Cordillera and Whitehorse Trough, where a long, narrow depocentre oriented along tectonic strike became segmented into subbasins (Johannson, 1994).

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