# LOWER JURASSIC VOLCANISM OF THE STIKINE SUPER-TERRANE*

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## INTRODUCTION

The Stikine super-terrane formed by the "docking" of the Quesnel, Cache Creek and Stikine terranes in Late Triassic times. Triassic arc volcanism, subalkaline at first, became shoshonitic as the subduction zone was disturbed by the collision of these terranes, and ceased thereafter. The shoshonites and associated more sodic alkaline rocks form the greatest part of the Nicola, Takla and Stuhini arcs (Spence, 1985). Volcanism resumed during the Sinemurian, seemingly after a lull of at least 13 million years (Rhaetian and Hettangian). It was short lived on Quesnellia, generating the alkaline, mainly shoshonitic, Rossland and Horsefly groups during the Sinemurian. On Stikinia, volcanism was intense, widespread, long lived (Sinemurian to Bajocian) and of mainly calcalkaline character; it is represented by the Hazelton Group and "Toodoggone Volcanics".

The purpose of this paper is to re-examine the available chemical data for these Jurassic volcanic sequences and to redefine their magmatic trends more precisely. The volcanic sequences for which data are available include the Elise Formation and Tillicum Mountain basalts of the Rossland Group, the Horsefly Group, the Telkwa and Nilkitkwa formations of the Hazelton Group and the lower "Toodoggone Volcanics". This paper documents (1) the presence of shoshonites in the Horsefly Group and emphasizes the importance of shoshonitic volcanism in the Quesnel trough, and (2) the chemical distinction between two types of calcalkaline suites in the Hazelton and Toodoggone groups.

Magmatic trends were determined by extracting analyses of "unaltered" samples using the MgO versus CaO diagram and examining their patterns on several diagrams. These diagrams and a nomenclature based on a purely chemical classification scheme were presented previously (de Rosen-Spence, 1976; Spence, 1985; de Rosen-Spence and Sinclair, 1987). As a reminder, the term "calcalkaline" is used here for alkali content intermediate between calcic and alkaline, as determined on the alkali versus silica diagram; it is absolutely descriptive and does not presuppose an absence of iron enrichment, whereas the terms "iron rich" and "iron poor" refer to what is described elsewhere as tholeiitic and calc-alkaline trends. Petrographic nomenclature of root names follows the recommendations of the I.U.G.S. Commission on Systematics in Petrology (Zanettin, 1984). Rocks of the shoshonitic suite were given their subroot names to distinguish them from other alkaline rocks because this suite is an important indicator of collisions. This peculiar suite is characterized by a subalkaline sodium content and very high to extremely high potassium content (VHK and EHK).

## VOLCANISM ON QUESNELLIA

The lower Jurassic sequences analysed are all from the southern (Elise Formation, Tillicum Mountain basalts) and central (Horsefly Group) Quesnel trough and are thus submarine except for the upper Horsefly Group which emerged as an island.

### ROSSLAND GROUP

#### ELISE FORMATION

The Elise Formation has been described in detail and analysed by Beddoe-Stephens (1982) who recognized its shoshonitic nature. It comprises a thick sequence of mainly brecciated and agglomeratic ankaramites, absarokites and shoshonites, as well as some high potassium basalts and basaltic andesites which commonly are associated with shoshonites (revised petrographic names). The Elise Formation has since been dated as Sinemurian by fossils (Tipper, 1984).

#### TILLICUM MOUNTAIN BASALTS

The Tillicum Mountain basalts have been described and analysed by Kwong (1985) and Ray (Ray and Spence, 1986). They are also shoshonitic, more precisely absarokites, and have been correlated on the basis of their composition with the Elise Formation only 60 kilometres to the south (Ray and Spence, 1986). No other volcanic rock types have been identified, but the Tillicum Mountain basalts are intruded by high potassium dioritic sills which probably are related to the same igneous episode. This basaltic belt continues northwestward through Vernon and beyond, but no data are available to characterize its composition.

### HORSEFLY GROUP

The Horsefly Group was isolated from the Quesnel River Group by Morton (1976) who recognized its alkaline character, but not the presence of shoshonites, nor its arc setting (low titanium content). He identified three distinct

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volcanic cycles, each with its set of small intrusions following an episode of extensive alkaline basaltic volcanism.

The Horsefly Group is fairly well preserved overall and the plots of the "unaltered" samples show the first cycle to be clearly shoshonitic, and composed mainly of absarokites with a few shoshonites and latites. The second and third cycles, although mostly as potassic (very high potassium) as the first cycle, are also more sodic, and thus are defined here as "potasso-sodic"; they comprise alkali basalt, trachybasalt and basaltic trachyandesite. The association of shoshonitic and potasso-sodic suites is very common in the alkaline arcs of British Columbia. All three cycles show a low titanium content and iron-poor trend characteristic of an arc setting.

Analyses from a smaller area of the group reported by Panteleyev (1987) are mainly from ankaramites and thus difficult to attribute to the shoshonitic or potasso-sodic suites. Basaltic trachyandesites, mildly alkaline shoshonites and high potassium basalt are also present.

The age of the Horsefly Group is not well constrained because fossils are rare and outcrops sparse; it is considered lower Jurassic by Morton (1976), but mainly upper Triassic by Bailey (1978) who mapped an area further north than Morton. According to Panteleyev (1987), Sinemurian fossils, gathered by Tipper, occur in the middle of the sequence in a sedimentary unit intruded by the seemingly shoshonitic Shiko stock dated as Pliensbachian-Toarcian. Thus, at least a part if not all of the Horsefly Group is Sinemurian. It could, however, include some upper Triassic shoshonitic basalts at its base as it is situated at the junction of the northward extensions of the Nicola and Rossland belts.

### DISCUSSION

The Nicola shoshonitic belt is associated on the west with a calcalkaline belt (Preto, 1979; Mortimer, 1986) and is therefore thought to be related to the destruction by collision of the then active Cache Creek subduction zone. The Rossland-Horsefly belt, on the other hand, shows no signs of normal subalkaline volcanism (its high potassium basalts are not part of a "normal" suite). It was formed **after** a period of quiescence (Rhaetian and Hettangian) following the destruction of the Cache Creek subduction zone and, in its southern end, it is situated 200 kilometres to the east of that zone. It cannot, therefore, be a direct continuation of the Nicola volcanism as has been suggested (Monger, 1985; Mortimer, 1986). A parallel to events in the eastern Mediterranean (Kolios *et al.*, 1980) is proposed here: that the Rossland-Horsefly shoshonitic volcanism was generated in a zone of local extensional stress (Quesnel trough) created by the continuing oblique pressure of Stikinia against Quesnellia after the destruction of the subduction zone and before the lateral northward slip of Stikinia relieved this stress. Although not the direct continuation of the Nicola, the Rossland-Horsefly volcanism can be considered to have been the last volcanic gasp of the tectonic cycle which generated the Nicola arc.

## VOLCANISM ON STIKINIA

Volcanism on Stikina differs from that on Quesnellia in composition and duration. It is mainly calcalkaline, although alkaline suites are (or may be) present, and it spans the Sinemurian to Bajocian interval. Volcanic sequences are grouped in the Hazelton Group along the southern and western edges of the Bowser basin and in the "Toodoggone Volcanics" along the eastern and northeastern margin.

Plots of "unaltered" samples of the Hazelton Group and "Toodoggone Volcanics" are illustrated on Figures 1-19-1 to 1-19-4.

### HAZELTON GROUP

#### TELKWA FORMATION

The Sinemurian Telkwa Formation at the base of the Hazelton Group is entirely volcanic. Tipper and Richards (1976) subdivided it into five facies which are, from west to east: subaerial Howson, shelf Babine, submarine Kotsine, subaerial Bear Lake and Sikanni. They provided analyses for the Howson, Kotsine and Bear Lake (Bait Range) and showed that the Bear Lake facies was more sodic and alkaline and less rich in iron and titanium than the Howson and Kotsine facies. Additional data for the Bear Lake (Two Lake Creek) and Sikanni facies are found in Monger (1977) and Church (1976).

Reinterpretation of the data confirms Tipper and Richards' findings. The use of different plots and consideration of only "unaltered" samples allow for more confidence, although widespread zeolitization clouds the determination of the original trends.

**Howson Facies:** This sequence is a bimodal association of basaltic flows and rhyolitic ash-flows and flows belonging to a moderately potassic (Figure 1-19-1), subalkaline (Figure 1-19-3), mildly calcic (?) and mildly iron rich (tholeiitic

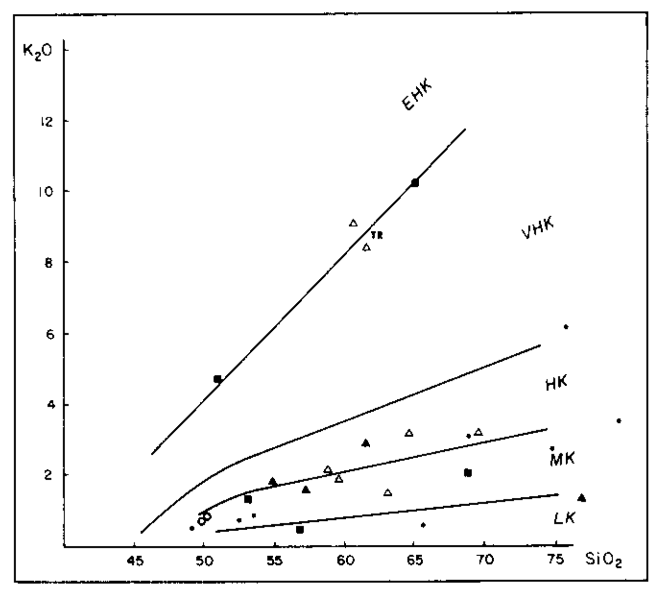


Figure 1-19-1. $K_2O$ versus $SiO_2$ for the Hazelton Group: Howson (filled circles), Bear Lake (filled squares) and Sikanni (filled triangles) facies, Ankwell basalts (open circles); and for the lower "Toodoggone Volcanics" (open triangles, TR = Toodoggone trachyte (two samples)). Only "unaltered" samples plotted from analyses recalculated 100% dry. Data are from Church (1976), Tipper and Richards (1976), Monger (1977) and Foster (1984) and domains from de Rosen-Spence (1976).

trend) (Figure 1-19-4) suite. It may reflect conditions of extension in the arc, possibly in the arc tholeiitic zone, if the sequence is truly calcic.

**Kotsine Facies:** This facies consists of altered flows and tuffs of basalt and basaltic andesite composition and can be attributed to a subalkaline, moderately potassic, mildly iron rich suite similar to that of the Howson facies. Its submarine deposition and mafic character suggest a more prominent extension of the arc in that area.

**Bear Lake Facies (Bait Range and Two Lake Creek Area):** This is an altered succession of basalt, basaltic andesite, dacite and rhyolite flows and tuffs; some trachyte flows are also present. The sequence plots as mainly moderately potassic (Figure 1-19-1), alkaline (Figure 1-19-3), very sodic (Figure 1-19-2), iron poor (Figure 1-19-4), and is richer in aluminum and poorer in titanium than the Howson facies. Because of the extensive alteration involving the formation of calcite and exchanges between sodium and potassium, it is likely that samples classed as "unaltered" are actually also somewhat altered; it is not possible to classify this sequence with certainty as an alkaline sodic suite, only as a probable one.

**Sikanni Facies:** This is a succession of basalt, basaltic andesite, andesite, dacite and rhyolite flows and tuffs, apparently less altered than the Bear Lake facies. It can be considered a medium to high potassium (Figure 1-19-1), calcalkaline (Figure 1-19-3) suite, iron poor (Figure 1-19-4), and belonging to an arc of Type II (Figure 1-19-5) (de Rosen-Spence and Sinclair, 1987). It differs from the Howson facies by the complete petrographic range from basalt to rhyolite, lower iron and titanium, slightly higher potassium contents and the well-defined calcalkaline content, whereas the Howson facies seems to be more calcic and iron rich. The Sikanni facies is similar to the Pliensbachian Toodoggone sequence to the north.

## Nilkitkwa Ash-fall Tuffs

The Nilkitkwa ash-fall tuffs are interbedded with sediments of Pliensbachian age; they are andesitic to rhyolitic and belong to a moderately potassic, subalkaline, mildly iron rich arc suite. Hence, they belong to a group chemically similar to the Howson facies, but their altered state prevents a more precise classification into calcic or calcalkaline.

## Ankwell Basalts

The Ankwell basalts are submarine flows and aquagene tuffs of Toarcian age. They form the top member of the Nilkitkwa Formation in the Hazelton trough and are time equivalent with the subaerial rhyolitic Red Tuffs member on the southwestern edge of the trough. They plot as moderately potassic, calcalkaline high alumina basalts.

## Hazelton Group in the Stewart Mining Camp

In the Stewart mining camp, the Hazelton Group is represented by a thick succession of waterlain andesitic tuffs. Data from Alldrick (1985) show them to be altered and commonly silicified. In spite of this they can be classed as subalkaline and mildly iron rich, similar to the Howson facies or the Nilkitkwa tuffs.

## "TOODOGGONE VOLCANICS"

The "Toodoggone Volcanics" are a subaerial arc assemblage of Pliensbachian to Bajocian age (Gabrielse, 1978; Smith *et al.*, 1984) situated along the northeastern margin of the Hazelton trough. They are time equivalent with the mostly sedimentary Nilkitkwa and Smithers formations of the Hazelton Group. All data available (Schroeter, 1982; Foster, 1984; H. Gabrielse, personal communication, 1985) are from the Pliensbachian succession in the Toodoggone River area, that is, they represent the lower "Toodoggone". Only a few analyses from samples of uncertain age were available from the Cry Lake map area (Anderson, 1983). In the Toodoggone River area, some andesites have been as-

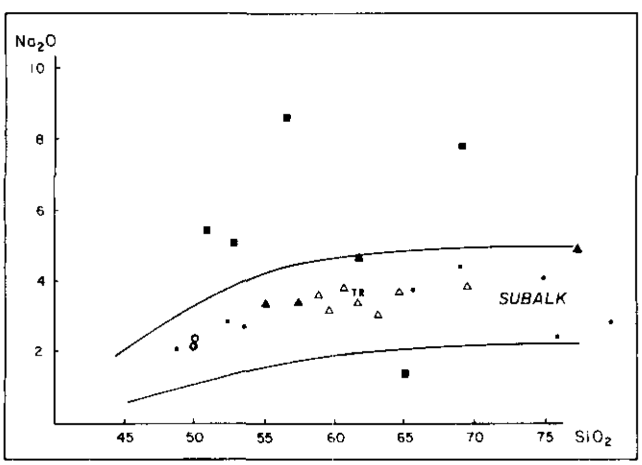


Figure 1-19-2. $Na_2O$ versus $SiO_2$ for the Hazelton Group and "Toodoggone Volcanics". Legend as in Figure 1-19-1.

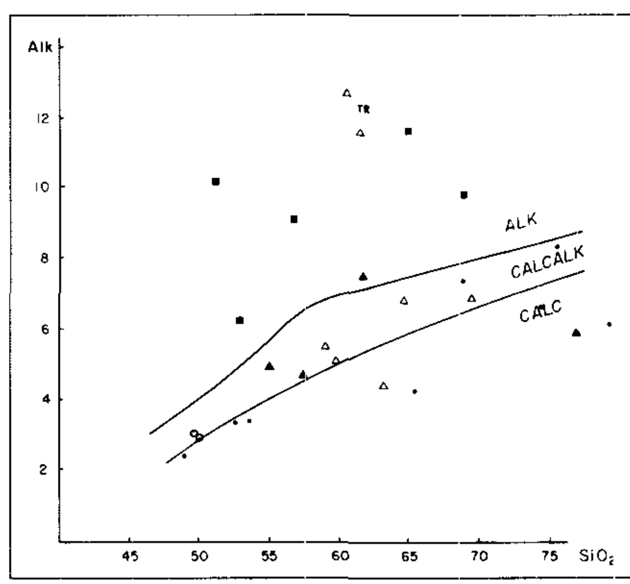


Figure 1-19-3. Alkali versus $SiO_2$ for the Hazelton Group and "Toodoggone Volcanics". Legend as in Figure 1-19-1.

signed to the Hazelton Group (Telkwa Formation), but have not been dated; they are treated with the "Toodoggone Volcanics".

## Lower "Toodoggone Volcanics"

In the Toodoggone River area, the "Toodoggone Volcanics" of Pliensbachian age rest unconformably over the Upper Triassic Takla Group. According to Schroeter (1982), Panteleyev (1983) and Foster (1984), they consist mainly of a succession of andesitic flows and pyroclastic deposits followed by potassic trachyte, the whole being blanketed by extensive dacitic ash flows.

In spite of widespread and varied alteration related to gold mineralization, the andesitic and dacitic succession analysed by Foster (1984) can be interpreted as a medium to high potassium, calcalkaline and iron-poor suite of arc Type II (Figure 1-19-5). The trachyte is potassic (TR on Figures 1-19-1 to 4). In the set of samples analysed, the most prevalent alteration is silicification accompanied by loss of calcium and some gain of sodium in the dacitic ash flows; in addition, andesites modified by potassic alteration near mineralization mimic the composition of shoshonites. In the same area, the succession analysed by Schroeter (1982) comprises some high potassium andesites, apparently an absarokite and shoshonite, and altered shoshonitic trachyte tuffs.

## Hazelton Group East of the "Toodoggone Volcanics"

A succession of andesitic pumice-breccia and flows situated to the northeast of the "Toodoggone Volcanics," and separated from them by a fault, has been assigned to the Hazelton Group on the basis of its similarity to the Sikanni facies of the Telkwa Formation. It also rests unconformably on the Takla Group. No fossils are known in the Sikanni or in this sequence of "Hazelton" to verify the correlation and their assigned Sinemurian age.

Data from Foster (1985) and Gabrielse (personal communication, 1987) show that the andesites have suffered from some sodium-potassium exchanges and thus are difficult to classify with certainty; they probably are high potassium subalkaline andesites but could include some mildly alkaline latites. They are similar to the Toodoggone high potassium andesites.

In the Toodoggone River area, the identification of bona fide shoshonites is hampered by alteration, mainly by the common exchange of sodium and potassium and the existence of demonstrated potassic alteration near mineralization. The zirconium content has been used to separate altered subalkaline and alkaline suites (Winchester and Floyd, 1976) because it is generally considered "immobile". Zirconium data from Foster (1984) give a subalkaline classification for all the "Toodoggone", including the potassic trachyte flow and the "Hazelton" samples. The only alkaline sample is a sodic trachyandesite. Whether zirconium is diagnostic in this case may be open to question because of the widespread addition of $CO_2$ and the suggestion by Hynes (1980) that zirconium is mobile during carbonatization.

## DISCUSSION

Two main types of subalkaline suites can be recognized in the lower Jurassic arc volcanism of Stikinia. The first is a subalkaline, moderately potassic, mildly iron-rich suite, represented by the western Hazelton Group, excluding the Bear Lake and Sikanni facies. This type seems to have been deposited during extension of the arc. The second type is a subalkaline, medium to high potassium, iron-poor suite represented by the Sikanni facies of the Telkwa Formation, the "Toodoggone Volcanics" and the "Hazelton" Group in the Toodoggone area. Alkaline suites may be present and would be represented by the sodic Bear Lake facies of the Hazelton

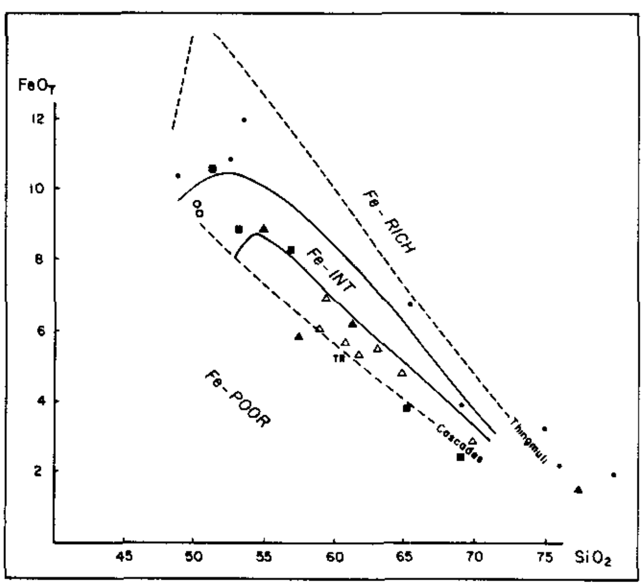


Figure 1-19-4. $FeO_T$ versus $SiO_2$ for the Hazelton Group and "Toodoggone Volcanics". Legend as in Figure 1-19-1.

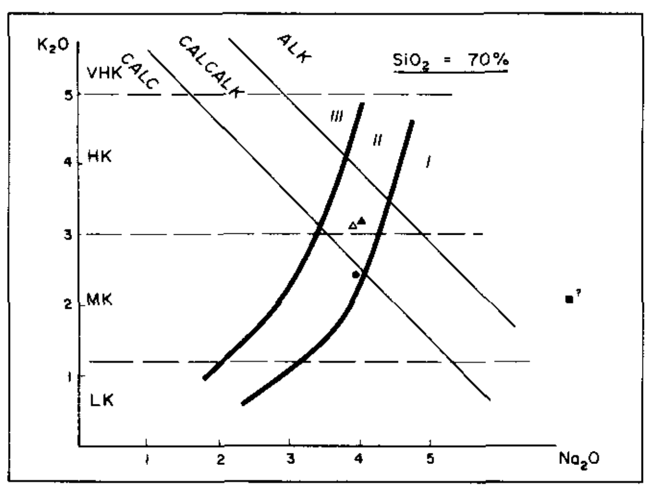


Figure 1-19-5. $K_2O$ versus $Na_2O$ for 70% $SiO_2$, showing the classification into arc types of the Howson, Bear Lake and Sikanni facies of the Hazelton Group and of the "Toodoggone Volcanics". Domains from de Rosen-Spence and Sinclair (1987) and legend as in Figure 1-19-1.

Group and the shoshonitic trachytes of the "Toodoggone Volcanics" if their alkalinity could be confirmed by additional petrographic and chemical data.

The arc is postulated to have been generated by the subduction of the Bridge River – Anyox(?) ocean in probably three episodes:

(1) During the Sinemurian, a new arc formed along the edge of Stikinia under extensional conditions, the Howson formed a western chain characterized by mildly iron-rich, probably calcic (arc tholeiitic) products. To the east an extensional trough developed and was filled by the Kotsine basalts, also iron-rich. An eastern chain composed of both the Bear Lake and Sikanni is difficult to reconcile because of their apparent difference in alkalinity. If the Sikanni is truly Sinemurian (it has no fossils) and the Bear Lake is truly alkaline, then the Bear Lake—which is a little older than the Kotsine—does not belong to the Hazelton cycle and its western subduction zone; instead it could be considered a last gasp of the Takla alkaline volcanism reactivated by the new tectonic conditions. If instead, the Sikanni is younger and part of the Toodoggone cycle (it has the same composition), then the Bear Lake can be an alkaline chain associated with the Howson chain. Alternatively, the Bear Lake is truly calcalkaline and associated with the Sikanni in a calcalkaline chain.

(2) The second episode, during the Pliensbachian and Toarcian, is marked by a shift of the main activity inland to form the calcalkaline Toodoggone chain, while much reduced episodic activity persisted to the west. The presence of shoshonitic trachytes, if confirmed, would indicate a disturbance of the subduction zone during the Pliensbachian.

(3) The third episode, during the lower Bajocian, is represented on the Stikine arch (Gabrielse, 1978) and in the Smithers Formation south of the Skeena arch, where it is deposited directly on the Telkwa Formation (Tipper, 1979).

## CONCLUSION

The lower Jurassic volcanism on the Stikine super-terrane is different on Quesnellia and Stikinia and reflects two different tectonic environments. On Quesnellia, the shoshonitic volcanism is the last gasp of the upper Triassic arc magmatism; it was generated in a local zone of tension formed by continued pressure of Stikinia against Quesnellia, long after the Cache Creek subduction zone had been destroyed. On Stikinia, on the other hand, the subalkaline volcanism is the product of a new subduction, postulated to be that of the Bridge River ocean. Arc volcanism ended with the final collision against North America and intrusion of the mid-Jurassic plutons.

## ACKNOWLEDGMENTS

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