ON THE GEOLOGY OF THE TERTIARY WRANGELL LAVAS IN THE ST. CLARE PROVINCE, ST. ELIAS MOUNTAINS, YUKON

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ABSTRACT

The Wrangell lavas in the St. Clare province of southwestern Yukon are part of the larger Wrangell volcanic belt that has been active throughout the Late Cenozoic. These lavas have erupted in a transitional tectonic environment that reflects regional transpression along the Queen Charlotte transform-Fairweather-Totschunda Fault System and subduction of the Farallon Plate beneath North America. The volcanic province is composed of subalkaline basalt (31%), basaltic andesite (30%), andesite (21%), dacite (2%) and nepheline normative basalt (16%). The hypersthene normative basalt is (in order of appearance) spinel-olivine-plagioclase ± Fe-Ti oxide ± clinopyroxene phyric, whereas andesite contains plagioclase, Fe-Ti oxide, clinopyroxene, ± orthopyroxene phenocrysts, and dacite and intrusive latite contain phenocrysts of plagioclase, ± clinopyroxene, hornblende, ± biotite, ± sanidine. The nepheline normative rocks, where porphyritic, contain phenocrysts of olivine, plagioclase and hornblende. In the central part of the map area, the lowermost flows are nepheline normative basalt that is interbedded with clastic sediments and is overlain by basaltic andesite, andesite and volcanic conglomerate. This succession is overlain by basalt interbedded with clastic sedimentary rocks and pyroclastic rocks. In the southern part of the map area, alkaline basalt occurs at this stratigraphic level. The uppermost Wrangell lavas are andesitic with minor interbedded volcaniclastic rocks. The hypersthene normative lavas of the St. Clare province are transitional in terms of their Na_2O+K_2O/SiO_2 ratios between alkaline and subalkaline magma series and in terms of their FeO/MgO versus SiO_2 ratios between tholeiitic and calc-alkaline series. Chemical composition of these rocks reflects the unique tectonic setting within which they are found.*

INTRODUCTION

The Late Cenozoic Wrangell lavas in southwestern Yukon and Alaska occupy a key position in the tectonic history of the northwestern Cordillera. These volcanic rocks comprise a volcanic belt that erupted along a major tectonic transition in the Cordillera. Toward the southeast, the Pacific-North American plate boundary is the Queen Charlotte Transform Fault (Atwater, 1970; Coney, 1978; Ewing, 1980) which extends northwestward into the continent along the Fairweather-Totschunda Fault System (Fig. 1). In southern Alaska and beneath the Aleutian Arc the plate margin is a subduction zone. In the transition between the Queen Charlotte Fault and the Aleutian trench, the fault-bounded Yakutat block of the North American plate margin (Plafker, 1983), is in the process of accreting with North America. At the leading edge of the Yakutat block a fragment of the Farallon oceanic plate has been subducting beneath the continent throughout the Late Cenozoic (Luhr et al., 1980; Bruns, 1983; Nye, 1983). The Wrangell volcanic belt overlies the Farallon-North American subduction zone in the northwest (Stephens et al., 1983), and a transpressional tectonic zone in the southeast. This paper is a preliminary report of an ongoing PhD study by the first author into the nature of the magmatic and tectonic processes that controlled the evolution of the Wrangell volcanics in the St. Clare province of southwestern Yukon.

This study documents the chemical composition and petrography of Wrangell lavas from selected stratigraphic sections measured within the St. Clare province in southwestern Yukon between Steele, Count and Wolverine Creeks and the Donjek River Valley (longitude 139° 45′-140° 35′ W, latitude 61° 15′-61° 35′ N, Fig. 1). The study summarizes the available geological data on this part of the St. Clare province and attempts to refine the existing stratigraphic nomenclature by describing and correlating measured sections within the volcanic pile. Chemical characteristics of the lavas are related to their macroscopic features and stratigraphic associations with the intention of providing useful mapping criteria.

REGIONAL SETTING

Late Cenozoic volcanic activity in the northwestern Cordillera of Alaska and Canada is confined to two linear volcanic belts. Toward the east, within the Intermontane belt, is the broad Stikine volcanic belt, which is dominantly composed of Quaternary alkaline volcanic rocks (Souther, 1977 (Fig. 1). Further to the west, within the Insular belt, is a northwesterly-trending volcanic belt known as the Wrangell volcanic belt (Souther, 1977). This volcanic belt is found within the Wrangell Mountains of southeastern Alaska and the St. Elias Mountains and Kluane Range of southwestern Yukon and northern British Columbia (Fig. 1). The Wrangell volcanic belt is comprised of the Wrangell lavas, a stratigraphic unit of formational rank (Mendenhall, 1905; MacKevett, 1970; Souther et al., 1975) which consists mainly of subalkaline Miocene to Recent volcanic and related intrusive rocks (Wrangell Intrusives of Souther et al., 1975).

Within Alaska, the Wrangell lavas range in age from Late Miocene (10 Ma, K-Ar dating — Denton et al., 1969; Nye, 1983) to Recent as evidenced by historic fumarole activity on Mt. Wrangell (Mendenhall, 1905; Nye, 1983). There is a preponderance of Quaternary volcanic products throughout the Wrangell Mountains. The volcanic rocks are calc-alkaline in composition (Richter et al., 1976; Richter et al., 1979; Nye, 1983) and are composed dominantly of andesites (57-63 wt% SiO_2) with lesser amounts of basalt, basaltic andesite, dacite and rhyolite (Nye, 1983). Pyroclastic rocks are subordinate to lavas in the Alaskan part of the Wrangell belt (Richter et al., 1976; MacKevett et al., 1978; Nye, 1983).

In Canada, the Wrangell lavas include those rocks previously called, 'The Tertiary Volcanic Rocks' (McConnell, 1905, 1906; Sharpe, 1943; Bostock, 1952), 'Newer Volcanics' (Cairnes, 1915) and in the Kluane Lake area, 'St. Clare Group' (Muller, 1967; Souther et al., 1975). The lavas in the southwestern part of the Wrangell belt in Canada are of Tertiary age (6 - 16 Ma, K-Ar dating by Souther, (unpublished) in Eisbacher et al., 1977). Souther et al. (1975) subdivided the Wrangell Belt in Canada into three volcanic provinces (Canyon Mountain, St. Clare and Alsek volcanic provinces) based on their distinctive stratigraphic and structural characteristics. These volcanic provinces include various proportions of pyroclastic rocks and sub-aerial lavas of basaltic to rhyolitic composition which are associated with numerous felsic and some mafic intrusives.

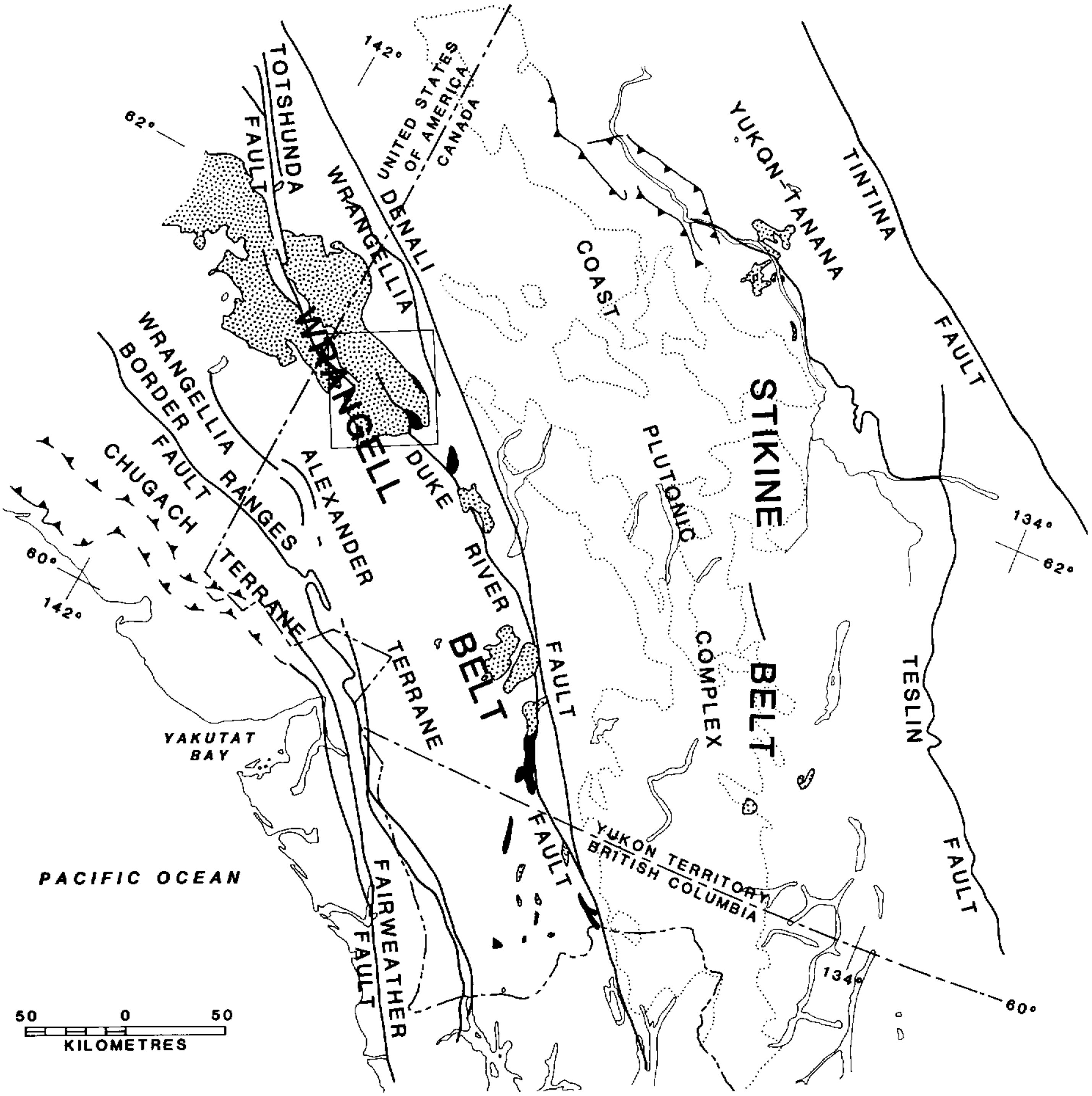


Figure 1. Location Map. The square shows the location of the study area in the St. Clare volcanic province. The dotted pattern represents the Wrangell lavas and the black pattern is the Amphitheater Formation.

PREVIOUS WORK AND GEOLOGICAL SETTING

Previous geological investigations in the study area include those of Sharpe (1943) into the Steele Creek area (Wolf Creek in his report) and Muller (1967) who produced a 1:253,440 scale map of the Kluane Lake area. The area was mapped in the 1970's by J. Souther of the Geological Survey of Canada at a scale of 1:125,000 as part of the St. Elias project, the results of which are found in the Geological Survey open-file map O.F. 829 (S.W. Kluane Lake Map Area, 115G and F (east half), Dodds, 1983).

In the central and northern parts of the map area, lowermost Wrangell lavas conformably overlie, and in places are interbedded with, continental clastic and coal-bearing sedimentary rocks of the Oligocene (?) Amphitheater Formation (cf. Muller, 1967; Eisbacher et al., 1977). The Paleozoic and Mesozoic basement to the Tertiary Amphitheater Formation and Wrangell lavas is exposed in the western and southeastern parts of the map area. Previous workers have shown that these basement rocks consist of two packages of stratigraphically distinct rocks that have been tectonically juxtaposed along the Duke River Fault (Fig. 2) (Muller, 1967; Dodds, 1983). South of the Duke River Fault, the Wrangell lavas unconformably overlie Devonian to Latest Triassic limestones and argillites in the Steele Creek area and Devonian massive to thick-bedded limestone and/or marble in the west near Klutlan Glacier. These rocks comprise a suspect terrane called the Alexander Terrane (Jones et al., 1977; Dodds, 1983). North of the Duke River Fault in the Steele and Cement Creek areas, the basement rocks underlying the Amphitheater Formation are composed of pre-Lower Permian gabbroic intrusive rocks (Dodds, 1983) and younger Latest Pennsylvanian to Lower Permian Skolai Group rocks of the Hasen Creek Formation (siliceous argillite, siltstone and older limestone and minor conglomerate). The Skolai Group rocks are themselves in-

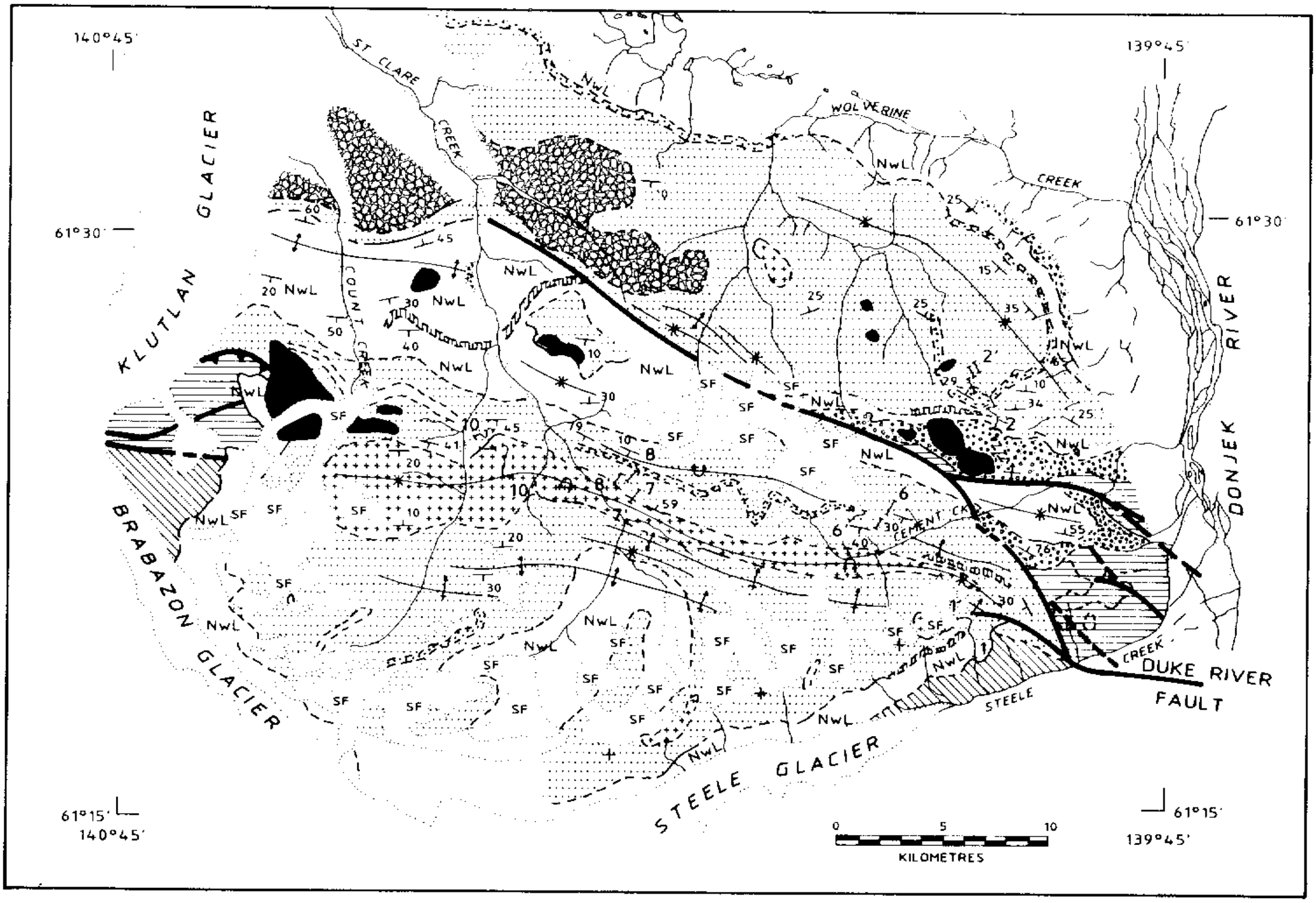
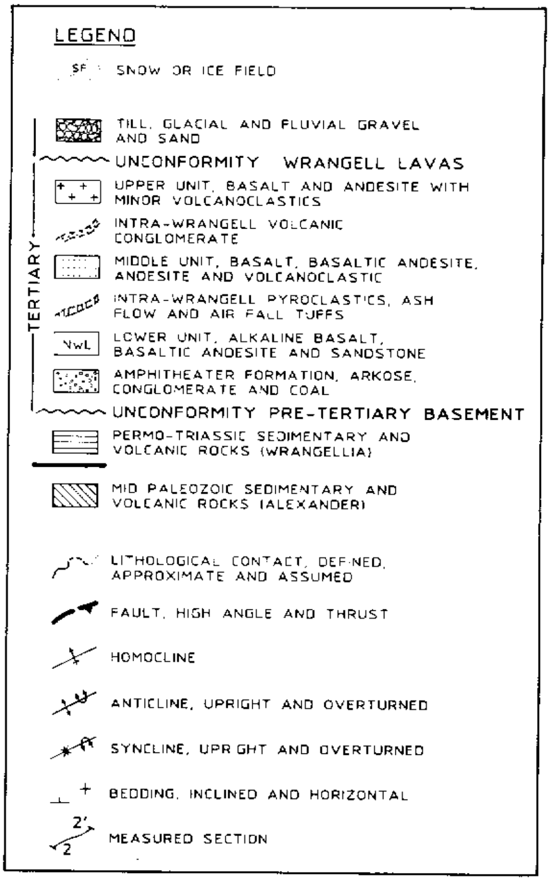


Figure 2. Geology of the Steele Creek Area. Geological map of part of the Wrangell volcanic belt, St. Clare province, St. Elias Mountains in the SW Yukon. Geology modified after Souther et al. (1975) and Muller (1967) and incorporating the results of the present study.



truded by Late Paleozoic to Mesozoic gabbro sills. In the easternmost corner of the map area, the Amphitheater Formation overlies Upper Triassic Chitistone and Nizina Limestones and Nikolai Greenstone. North of Cement Creek, the Amphitheater Formation unconformably overlies Pennsylvanian to Earliest Permian pyroclastic rocks of the Station Creek Formation. In the western part of the map area near Klutlan glacier, the Amphitheater Formation is not present and Wrangell lavas unconformably overlie and in places are in fault contact with the Steele Creek Gabbro Complex. All of these Paleozoic and Mesozoic basement rocks north of the Duke River Fault comprise a suspect terrane known as Wrangellia (Jones et al., 1977, Dodds, 1983).

Throughout Alaska and Yukon, all known contacts between the Wrangellia and Alexander Terranes are faults along which the juxtaposition of dissimilar Triassic sequences suggests post-Triassic docking of these two terranes. Since then, they appear to have comprised a composite terrane which was overlain by the Late Jurassic to Early Cretaceous Gravina and Nutzotin Mountain sequence in the eastern Alaska Range (Coney et al., 1980 and Monger et al., 1982). These terranes are believed to have been accreted to North America by Mid-Cretaceous time and migrated to the north from the Late Cretaceous to Early Tertiary along major strike-slip faults such as the Denali Fault System (Monger, 1984).

The Duke River Fault which separates the Wrangellia and Alexander Terranes in the map area is believed to be part of the Denali Fault System. It was originally mapped as a west-dipping thrust fault that postdated the emplacement of the Wrangell lavas (Muller, 1967). Souther et al. (1975), however, have shown that the main strand of the Duke River Fault cuts only the older Wrangell lavas in the Steele Creek area. Campbell et al. (1978) have suggested that the age of the principal displacement along the Duke River Fault is early or early Late Cretaceous and pre-Miocene. However, possibly related faults (Cement Creek Fault and unnamed fault, Fig. 2) cut the entire pile of Wrangell lavas between the Duke and Denali-Shakwak faults. Although the sense of displacement along these faults is enigmatic at present, they require that movement continued to Pliocene or younger time (Campbell et al., 1978; Clague, 1979). In addition, Souther et al. (1975) have shown that east of Klutlan glacier (Fig. 2), a young northerly-vergent thrust fault has juxtaposed Latest Pennsylvanian to Lower Permian Hasen Creek Formation rocks on lower Wrangell lavas.

It is clear that the Wrangell lavas were emplaced after most of the principal displacement along the major regional structures. Eisbacher et al. (1977) have suggested that the underlying Amphitheater Formation was deposited in small fault-bounded basins during Oligocene time. Paleocurrent data in the Cement Creek area suggest a westerly-directed sediment transport direction and K-Ar ages on detrital biotite in these sedimentary rocks suggests that the source area was east of the Shakwak Valley (Eisbacher et al., 1977). Eisbacher et al. have suggested that the present outcrop pattern indicates that the width of the valley into which the Amphitheater Formation was deposited must have exceeded 16 km. Furthermore, the present topographic contour interval between 2000 and 3000 m can be taken as the margin of clastic deposition during Amphitheater time, since the Wrangell lavas lie directly on older basement rocks above this elevation. Eisbacher et al. conclude that in mid-Tertiary time the St. Elias region was a rolling upland with wide shallow valleys and a temperate climate. Westward flowing drainage deposited blankets of gravel, sand, and coal into a broad valley and later faulting and folding accentuated local relief and triggered rockslides and debris flows (Eisbacher et al., 1977). It is within this intermontane setting that large volumes of Miocene Wrangell lavas are believed to have been subsequently erupted.

In Alaska, thick successions of tillite are interbedded with Wrangell lavas of Miocene to Pliocene age (10-3.6 Ma, K-Ar dating — Denton et al., 1969). Similar thick successions of folded tillite unconformably overlie Wrangell lavas in the northwestern part of the map area (Fig. 2), suggesting that in Miocene time the St. Elias Mountains may have attained an elevation sufficiently high to support thick sheets of ice (cf. Eisbacher et al., 1977). Continued Neogene uplift of the St. Elias Mountains has resulted in the folding and faulting of the Tertiary Wrangell lavas.

STRUCTURE OF THE WRANGELL LAVAS

The generally excellent exposure afforded by this alpine terrane, and the differential weathering habit of the stratigraphic units permits the tracing of large scale structures for considerable distances on the ground and in aerial photographs.

Souther et al. (1975) have shown that the structural style within the map area (Fig. 2) is highly variable. The trend of the hinge lines of major folds is west-northwest and large scale folds can be traced for distances up to 30 km in the map area. Structural style changes from north to south in terms of the density of folds and the geometry of individual folds. In the southern part of the map area, the Wrangell lavas are flat-lying, whereas a few kilometers toward the north they are folded into a north-dipping homocline. Toward the west-northwest, these north-dipping homoclinal structures trend into upright anticlines and then into a tightly folded syncline-anticline pair that is overturned to the south (north-dipping) with dips of approximately 80° in the vicinity of the southeast branch of St. Clare Creek. Further toward the west-northwest in the vicinity of the southwest branch of St. Clare Creek, the syncline becomes upright and open with limbs dipping at 20°. The core of this synclinal structure exposes the youngest stratigraphy in the area.

Souther et al. (1975) pointed out that even in the most intensely folded successions, such as in the St. Clare Creek valley, the internal disruption and deformation of the Wrangell lavas is minimal. Furthermore, the lavas have undergone a minimum of burial metamorphism, with zeolite facies representing the peak metamorphic conditions.

STRATIGRAPHY of the WRANGELL LAVAS

Souther et al. (1975) subdivided the Wrangell lavas in the St. Clare province into three informal units:

(NwL)

A lower unit comprising thick, blocky flows of mainly nonporphyritic basaltic andesite; locally separated by layers of white or light grey clay and coaly siltstone; overlain by a succession of 20 to 40 uniformly thin (0.6 to 1.8 m) closely stacked basaltic andesite flows with no interflow clastic or pyroclastic material.

(NwM)

A middle unit comprising both porphyritic and nonporphyritic basaltic andesite flows and minor pillow lavas, interlayered with a relatively high proportion of felsic ash flows, air fall, and volcanic derived sedimentary deposits including coaly tuff, sandstone and conglomerate.

(NwU)

An upper unit comprising basaltic flows and scoria, volcanic conglomerate, light grey dictytaxitic andesite and olivine basalt (Souther et al., 1975).

In this study, a series of six stratigraphic sections were measured through the volcanic pile of the St. Clare province. Rocks were classified using a two tiered system, first on the basis of SiO_2 weight percent abundance (normalized to 100% volatile free) and second on the presence or absence of nepheline in the norm (calculated assuming Fe_2O_3 = 0.1 Fe total). The arbitrary limits used for the subdivision of the rocks are: basalt (less than 52.0%), basaltic andesite (greater than, or equal to 52.0% and less than 55.0%), andesite (greater than, or equal to 55.0%, and less than 63.0%), dacite (greater than, or equal to 63.0%, and less than 70.0%) and rhyolite (greater than, or equal to 70.0%). A total of 155 whole rock analyses are available from the study area; 31% are basalts, 30% are basaltic andesites, 21% are andesites, 2% are dacites and 16% are nepheline normative basalts. Rocks which were not analysed were classified by comparison with analysed rocks using parameters such as colour, hardness, weathering habit, mineralogy, and abundance of phenocrysts.

PETROGRAPHY OF THE WRANGELL LAVAS

Rocks of basaltic composition in the Wrangell lavas are found as massive flows with vesicle-rich (in places amygdaloidal) oxidized flow tops with smooth or brecciated surfaces. These massive flows range in thickness from less than 5 m (relatively rare) up to 40 m, with most flows around 10 m. Most basalt flows have dark grey to dark green-grey fresh surfaces and brown-grey and brown weathered surfaces. Both porphyritic (the most abundant) and equigranular ophitic basalts are found.

Porphyritic basalts typically contain around 10% phenocrysts (all mineral abundances quoted are based on visual estimates) but can range from 5 to 40%. The phenocrysts are typically small (less than 1.5 mm) but locally plagioclase phenocrysts can range in size up to a few millimetres. The phenocrysts observed are olivine with tiny opaque mineral inclusions (spinel (?)), plagioclase and less commonly clinopyroxene and an opaque phase (Fe-Ti oxide (?)). In rocks with olivine, plagioclase and clinopyroxene phenocrysts, the relative proportion of plagioclase although variable, is typically around 60%, the remainder being typically olivine and minor amounts of clinopyroxene. Olivine almost always shows at least some alteration to geothite, talc or carbonate, which in the least altered grains appears to be concentrated on the margins and in fractures. Plagioclase phenocrysts are commonly zoned and may contain inclusions of olivine. Some rocks contain small glomerocrysts of olivine with laths of plagioclase on their outer margins. Paragenetic sequence of phenocrysts in these rocks is spinel, olivine, plagioclase, an opaque Fe-Ti oxide and clinopyroxene. Groundmass of the porphyritic basalts is commonly intersertal to intergranular and contains microlites of plagioclase (in places trachytic), anhedral granular clinopyroxene, and subhedral to cruciform opaques. Interstitial glass is commonly devitrified to fine, accicular anisotropic mineral(s) (clinopyroxene (?)) that are in turn commonly replaced by carbonate. Carbonate filled amygdules are less commonly present. The equigranular ophitic basalts range from fine to medium grain size and are composed of euhedral olivine, plagioclase with anhedral clinopyroxene which subophitically encloses plagioclase laths and subhedral opaque grains. Cores of some plagioclase grains contain olivine inclusions and similarly, some clinopyroxene contains plagioclase inclusions. Some of these rocks are ophimottled with small oikocrysts of clinopyroxene dispersed through the rock that contain plagioclase and olivine chadacrysts. Many of the equigranular ophitic basalts contain interstitial glass.

Basaltic rocks with nepheline in their norms are commonly equigranular and often indistinguishable from the other ophitic basalts. However, the lava flow near the base of Section 2 (Fig. 3) which contains the highest normative nepheline (10.25%) has a trachytic texture and contains phenocrysts of olivine, plagioclase and microphenocrysts of hornblende. The groundmass of this rock is comprised of plagioclase microlites, opaques and biotite.

The basaltic andesite is petrographically similar to the porphyritic basalt and is characterized by clinopyroxene phenocrysts. Size of phenocrysts tends to be larger in the basaltic andesites (up to 3 mm) and the abundance of plagioclase relative to olivine is higher than in the basalts. Only one basaltic andesite flow (Section 1) contains normative nepheline.

Andesite flows are easily identified in the field by their high abundance of plagioclase phenocrysts (up to 45%), the large size of phenocrysts (plagioclase up to 6 mm) and their highly vesicular (or amygdaloidal) nature. Commonly, the andesite flows are thin and have smooth flow tops. Colour of the flows is variable, but is generally grey on the fresh surface and pale grey or grey/brown on weathered surfaces. The andesites have an average phenocryst content of approximately 20% including olivine (rare), plagioclase (85%), opaque (Fe-Ti oxide, less than 5%), clinopyroxene (10%), and orthopyroxene (less than 5%). Paragenetic sequence of phenocrysts is olivine, plagioclase, Fe-Ti oxide (?), clinopyroxene and orthopyroxene. Groundmass is commonly trachytic consisting of microlites of plagioclase with clinopyroxene and opaques. Some andesites at the base of Section 2 contain cognate xenoliths that are plastically deformed and compositionally similar to extrusive rocks in the area.

Dacite occurs as comparatively rare thick flows (up to 100 m in Section 10). The fresh surface is grey and the weathered surface is generally pale-grey/pink or pale-brown. The flows commonly have thick brecciated tops with relatively thin massive portions. Dacites is always porphyritic with phenocryst contents around 25%. Phenocryst phases in order of appearance are plagioclase (75%), an opaque (Fe-Ti oxide (?), less than 5%), clinopyroxene (5%), orthopyroxene (trace), hornblende (20%), biotite (trace, commonly completely oxidized), apatite and zircon (less than 5%). The groundmass contains sanidine laths (?) and quartz.

Although fragmental deposits are subordinate to lavas within the Wrangell lavas, they act as useful marker horizons in the volcanic stratigraphy. Most of the pyroclastic rocks found within the Wrangell lavas are located within the middle unit (NwM). These include welded ash flow deposits such as those found on the northern margin of Wolverine Plateau, felsic air fall deposits, such as those found interbedded with fluvial conglomerates in the St. Clare Creek area and coarse grained matrix and clast supported volcanic conglomerates (NwCG) (Fig. 3). The volcanic conglomerates include both debris flow (lahar) and block and ash flow deposits.

Clastic sedimentary rocks including clast-supported conglomerate, subarkosic sandstone and low-rank coal seams are interbedded with the lower Wrangell lavas. These sedimentary rocks are identical to the underlying Amphitheater Formation. Clast-supported and imbricated conglomerates and cross-bedded sandstones occur within the middle unit (NwM). These rocks contain clasts that are exclusively of intra-Wrangell origin.

There are numerous intrusive bodies related to the Wrangell lavas. Some of these are high level sills or dykes and are petrographically similar to the lavas. A gabbroic sill in Cement Creek (Fig. 3) has a layered stratigraphy and reaches 150 m in thickness. Numerous felsic plugs intrude the Wrangell lavas, some reaching 6 km in width. Most plugs are porphyritic latite with phenocrysts (up to 40%) of sanidine, plagioclase, hornblende and biotite (both of which are generally oxidized). Groundmass of these rocks is fine-grained and contains laths of sanidine and possibly some quartz. Some of the plugs contain cognate xenoliths of surrounding wallrocks. The margins of many of the intrusive plugs are commonly sharp, brecciated and crosscut by thin quartz veins. Pyritization is locally prominent at the margins and within thin quartz veins (2-5 cm) crosscutting the interiors of the large intrusive plugs north of Cement Creek (Fig. 3). The exposed roof of one of these felsic plugs between the southwestern branch of St. Clare and Count Creeks is bleached and brecciated. Lavas that overlie this intrusive body are also extensively brecciated and bleached white, and all of their opaque minerals have been oxidized. A dense network of andesitic and basaltic dykes (up to 2 m in width) crosscuts the brecciated rocks. Alteration in these dykes is variable, some are heavily oxidized whereas other younger dykes have fresh glassy chill margins. Souther et al. (1975) describe similar intrusive relations and altered wallrocks in the vicinity of Brabazon Glacier.

CHEMICAL STRATIGRAPHY

Wrangell lavas in the St. Clare province straddle the MacDonald (1968) dividing line between alkaline and subalkaline compositions on a total alkalis versus silica diagram (Fig. 4). The nepheline normative rocks quite clearly lie in the alkaline field (Fig. 4). The amount of normative nepheline in the basalts of Section 1 is considerably lower (to 2.7%) than in those of Section 2. In Section 2, nepheline normative basalts occur interbedded with clastic sediments at the base of the section, whereas in Section 1, although a few nepheline normative rocks occur at lower stratigraphic levels, most occur in mid to upper levels in unit NwM (Fig. 3).

Distribution of rock types is generally consistent with the stratigraphy proposed by Souther et al. (1975). In Section 1, basaltic andesite is abundant in the lower unit (NwL), however, many of the flows of the middle unit (NwM) are nepheline normative and subalkaline basalts (Fig. 3). Characteristically, the upper unit (NwU) is rich in basalt. It is clear, however, that Section 1 is considerably thinner than the sections measured to the north. The lower Wrangell lavas in Section 2 are dominated by basaltic andesite but also contain previously unreported nepheline normative basalt. Lower to mid reaches of the middle unit (NwM) in Sections 2, 6 and 7 contain abundant flows of basaltic andesite and andesite, whereas basalt is more important in the upper reaches where flows are interbedded with fragmental rocks (Section 7). Upper parts of the Wrangell stratigraphy (NwU) in Sections 7 and 10 are andesite rich in contrast to the basalt that is characterisitic of the upper NwU unit defined by Souther et al. (1975).

It is premature to attempt large scale correlations in the map area due to the large distance between sections and lack of sufficient stratigraphic control. It is clear, however, that the fragmental rocks (volcanic and sedimentary) will play an important role in stratigraphic correlation in this area. The correlation between Sections 8 and 6 are based on their positions relative to the thick volcanic conglomerate that underlies 8 and occurs near the top of 6 (Fig. 3). The occurrence of andesitic lavas relative to this conglomerate is a particularly useful marker between Sections 2, 6 and 8. Correlation between Section 1 and the rest of the area is tenuous at present, because of the probability that this section, which is not underlain by Amphitheater rocks, was topographically high relative to the rest of the area (cf. Eisbacher et al., 1977).

CHEMISTRY OF THE WRANGELL LAVAS

The transitional tectonic setting of the Wrangell lavas is reflected in their chemical composition which is not easily classified in terms of type magmatic series. While a distinct group of rocks within the St. Clare province can be classified as alkaline on the basis of Na_2O+K_2O/SiO_2 ratios and normative nepheline, most lavas are hypersthene normative and transitional in terms of their alkali/silica ratios (Fig. 4). Assigning the hypersthene normative Wrangell lavas in the study area to either the tholeiitic or calc-alkaline magma series is also problematic. Although these lavas lie in the calc-alkaline field of an AFM diagram (Irvine et al., 1971, Fig. 6), they are not clearly discriminated in a plot of FeO*/MgO versus SiO_2 (Fig. 5), (cf. Miyashiro, 1974). Gill (1982) has observed, however, that many analyses of orogenic andesite (hypersthene normative rocks with SiO_2 of 53 - 63%, K_2O less than (0.145 x SiO_2) and TiO_2 less than 1.75%) considered calc-alkaline on the AFM diagram are tholeiitic using Miyashiro's (1974) criteria. The St. Clare lavas exhibit compositional characteristics which are transitional between alkaline and subalkaline series and tholeiitic and calc-alkaline magma series in terms of their alkali/silica and FeO*/MgO ratios and normative mineral compositions.

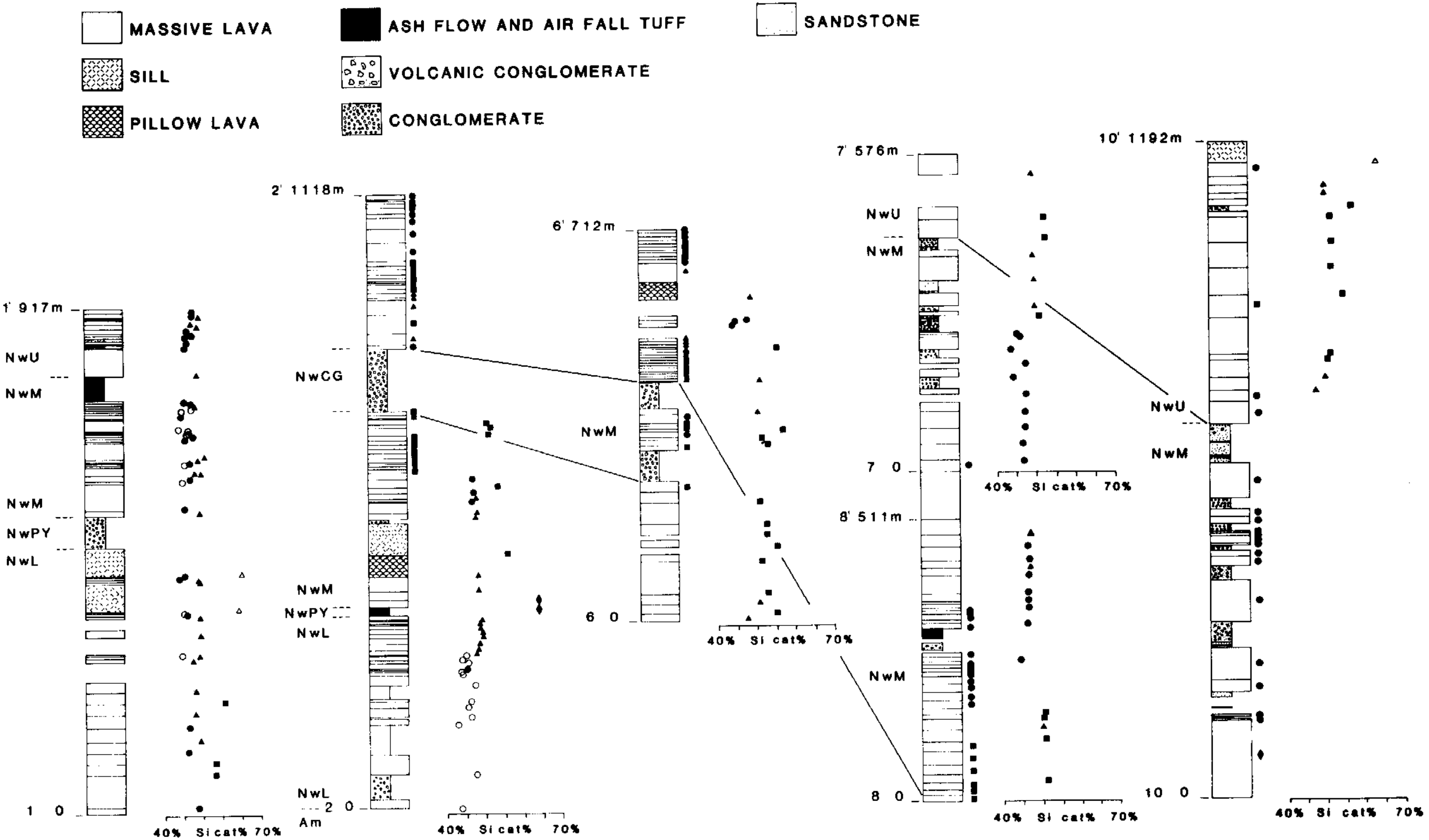


Figure 3. Stratigraphic Sections from the St. Clare Province. Location of measured sections is shown in Fig. 2. The whole rock analyses were made on a Phillips PW1400 x-ray fluorescence unit at McGill University. Open circle symbols represent nepheline normative basalts, dark circles are basalts, black triangles are basaltic andesites, black squares are andesites, black diamonds are dacites and open triangles are intrusive latites.

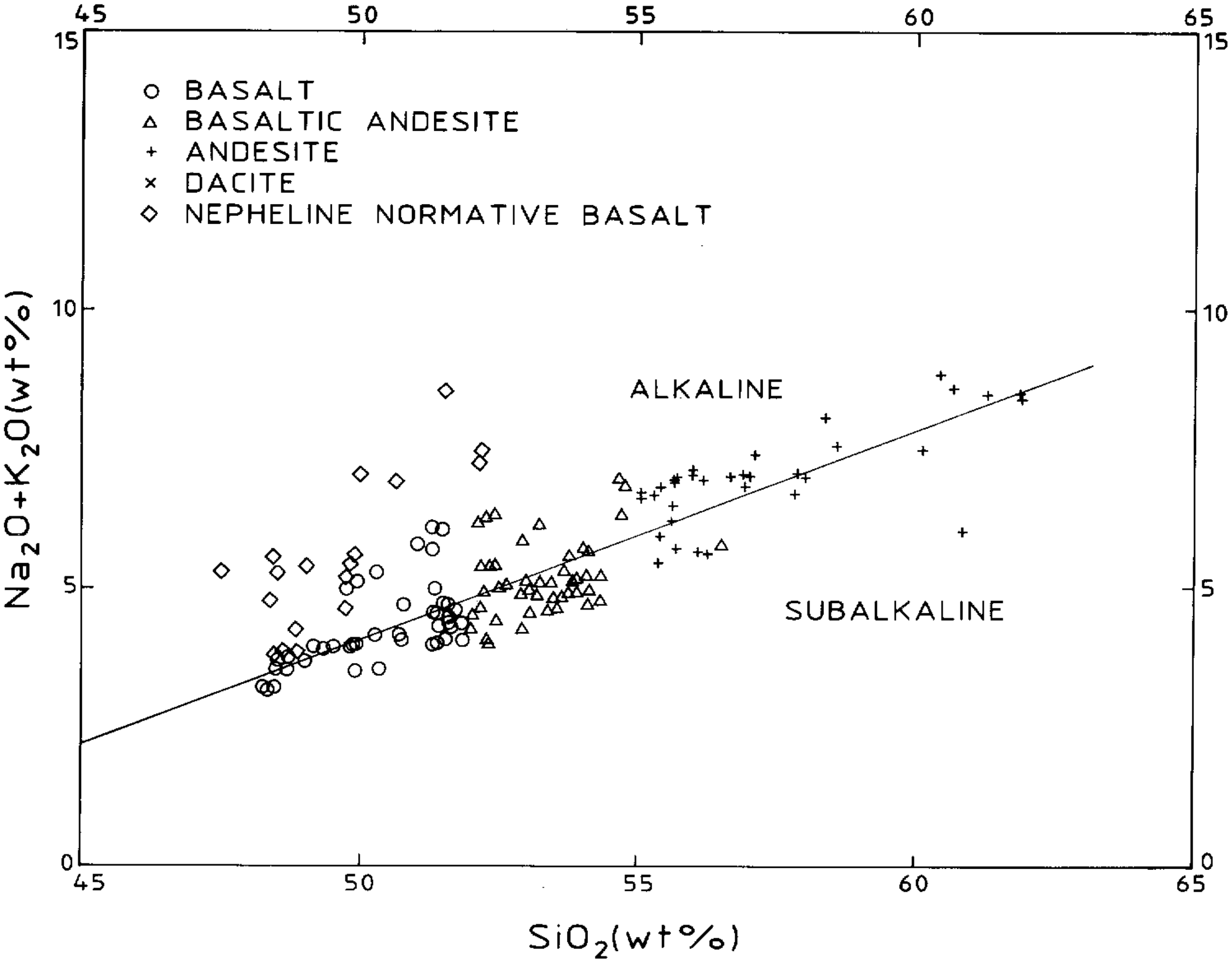


Figure 4. Total Alkalies Versus Silica Diagram. Analyses are presented on a normalized to 100% volatile-free basis. The dividing line is taken from Macdonald (1968) for Hawaiian volcanic rocks.

SUMMARY AND CONCLUSIONS

Approximately 2300 m of Mid-Tertiary Wrangell lavas are preserved in the central part of the St. Clare province in the St. Elias Mountains. The Wrangell lavas conformably overlie, and are in part interbedded with, clastic and coal-bearing cotinentally-derived sedimentary rocks of the Amphitheater Formation, all of which appear to have accumulated in intracontinental fault-bounded basins. The lowermost Wrangell lavas are crosscut by a strike-slip fault, the Duke River Fault, which is part of a large Late Mesozoic to Cenozoic system of dextral transcurrent faults in the northwestern Cordillera. Younger lavas of the St. Clare province, however, overlie this fault. Neogene deformation in this area resulted in the uplift of the St. Elias Mountains and the folding and faulting of the Wrangell lavas. This deformation, however, has been laterally heterogeneous. Over much of the area, the lavas are horizontal or gently folded whereas locally they are crosscut by faults and folded into tight overturned structures.

Wrangell lavas in the St. Clare province are composed of subalkaline basalt, basaltic andesite, andesite, dacite and latite (intrusive) as well as lesser amounts of alkaline basalt. Hypersthene normative basalt and basaltic andesite are (in their relative order of appearance) spinel - olivine - plagioclase ± Fe-Ti oxide ± clinopyroxene phyric whereas andesite contains plagioclase, Fe-Ti oxide, clinopyroxene, and late orthopyroxene phenocrysts and dacite and latite contain plagioclase, clinopyroxene, hornblende, and late biotite and sanidine phenocrysts. The alkaline basalt is commonly equigranular, although the most alkaline flow (10% normative nepheline) contains phenocrysts of olivine, plagioclase and hornblende.

Lowermost Wrangell lavas are composed of alkaline basalt interbedded with clastic sediments in the central part of the map area and hypersthene normative basaltic andesite and basalt in the south. Mid levels of the stratigraphy are composed of basaltic andesite, andesite, and a volcanic conglomerate that can be traced throughout a large part of the map area. These are in turn overlain by a thick succession of subalkaline basalt interbedded with clastic sedimentary rocks and felsic air fall tuff. In the southern part of the map area, alkaline basalt also occurs at this stratigraphic level. The youngest Wrangell lavas are mainly andesite with minor interbedded volcaniclastic rocks.

Mid to Late Cenozoic tectonics of the northwestern Cordillera is transpressional in the vicinity of the Queen Charlotte transform - Fairweather - Totschunda Fault System. Further to the north, the Farallon plate has been subducting beneath the North American plate. The Wrangell volcanic belt overlies the transition zone between these two tectonic regimes. In Alaska, the Wrangell lavas are calc-alkaline and are believed to have erupted over a Benioff Zone. Further to the south in the St. Clare province, the Wrangell lavas contain rocks of both alkaline and subalkaline affinity. The subalkaline rocks cannot be easily categorized as calc-alkaline or tholeiitic, since they share attributes of both series.

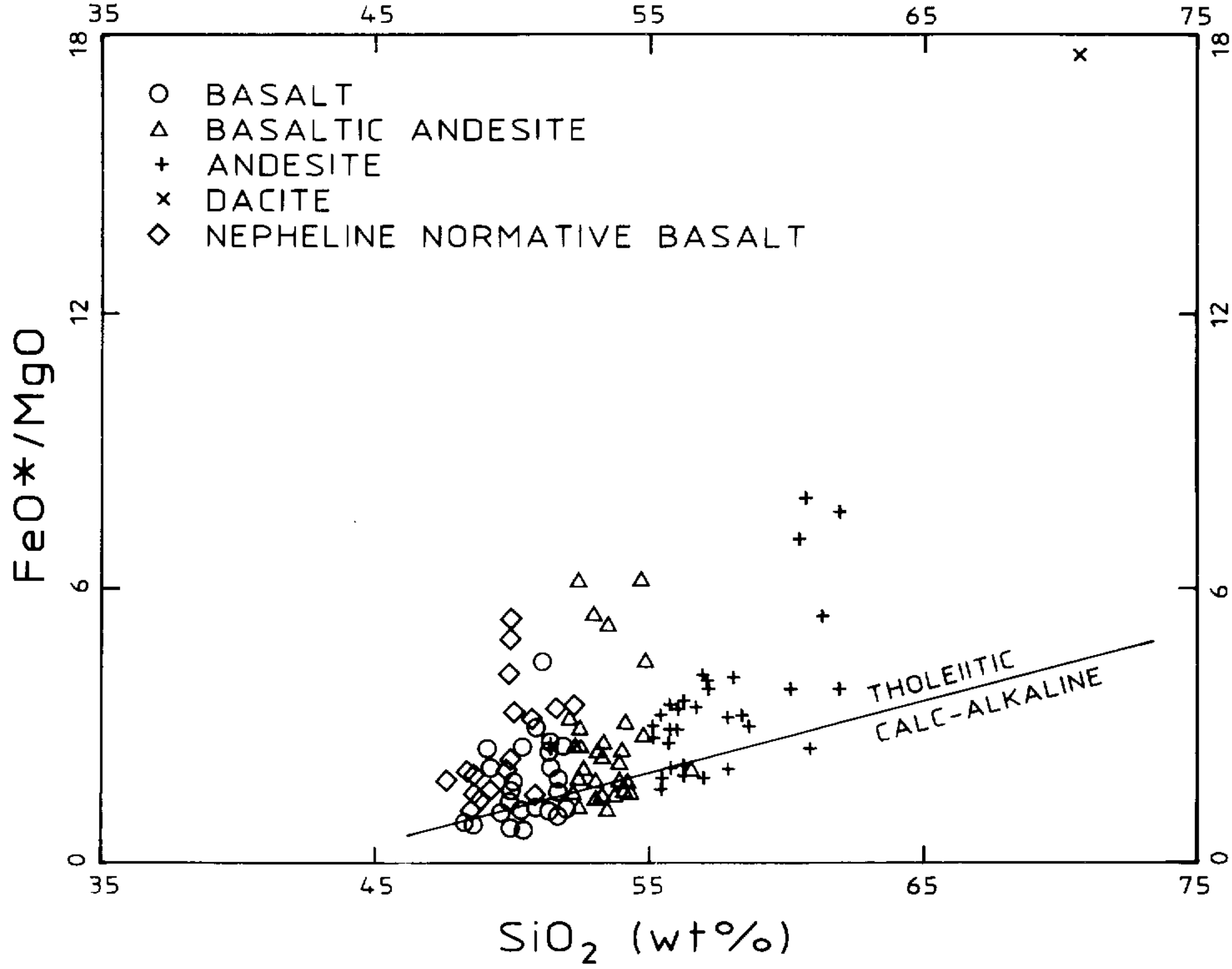


Figure 5. FeO*/MgO Versus SiO_2 Diagram. Total iron is calculated as FeO and all analyses are normalized to 100% volatile free. The dividing line is taken from Miyashiro (1974).

Future work in this study will concentrate on the relationship between the tectonic setting of these volcanic rocks and the processes which account for their transitional compositional affinities.

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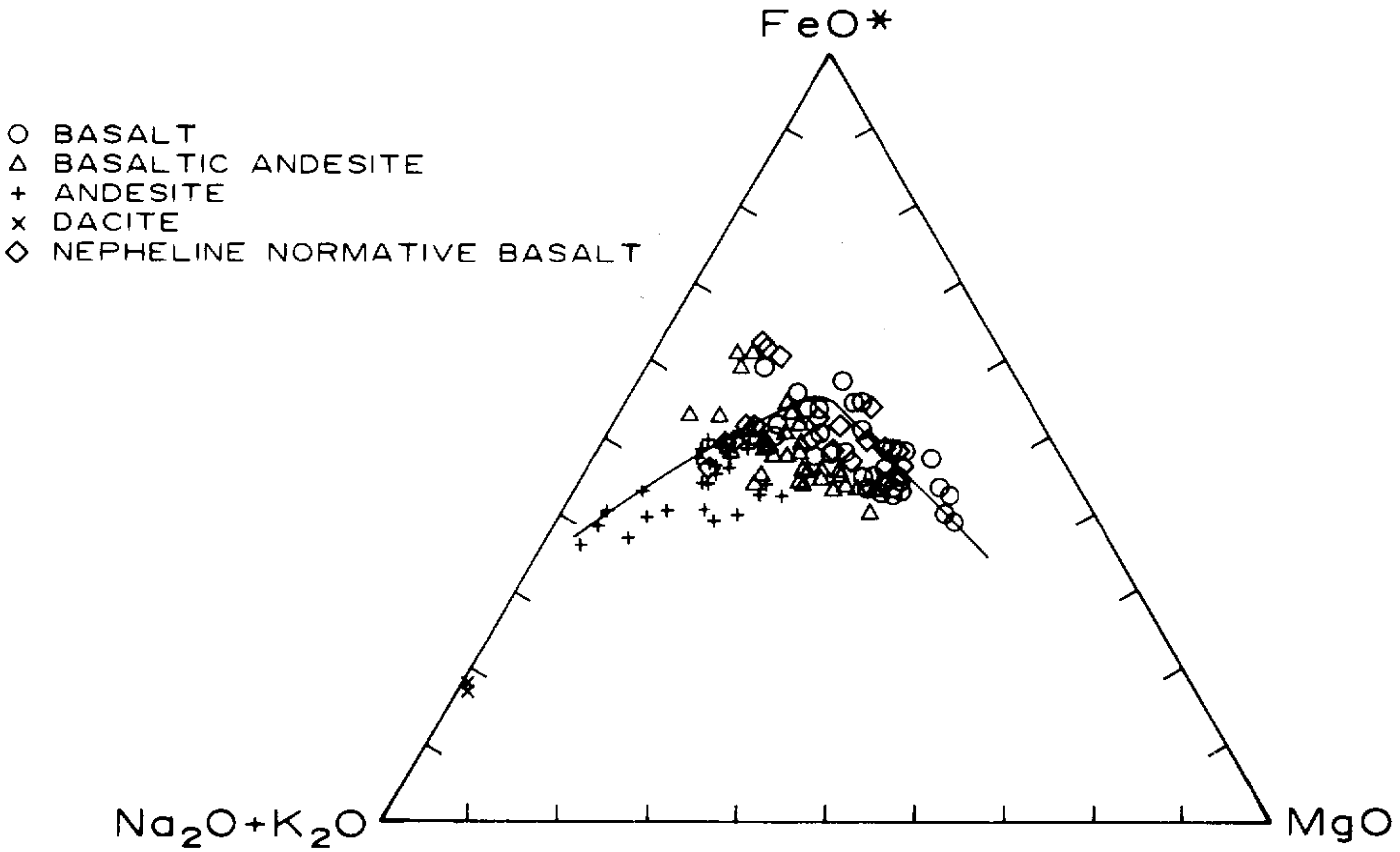

Figure 6. AFM Diagram. The analyses are in weight percent normalized to 100% volatile free. Total iron is calculated as FeO. The subdividing line between tholeiitic (above the curve) and calc-alkaline (below the curve) rocks is taken from Irvine et al. (1971).

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