WINDY CRAGGY

114P 2

Do deposit overview?

Don's Talk

1, 5, 31, 33

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Slide 1 ACCRETED TERRANES OF THE INSULAR TECTONIC BELT

This slide shows the major terranes of NW B.C. and SE Alaska. Going from west to east we have the Jurassic-Cretaceous Chugach Terrane coloured yellow, Wrangellia and equivalent Taku terrane coloured in green, the Alexander Terrane coloured in orange and the Coast Plutonic or Tracy Arm terrane coloured in red. The Alexander terrane is the subject of this talk. All of these terranes have been accreted to the leading edge of the North American craton. Paleomag evidence indicates the Wrangellia and Alexander terranes have moved northward from low Paleolatitudes, probably as one superterrane.

SLIDE 1

- Major terranes NW BC SE Alaska
- WEST → EAST
  - CHUGACH (YELLOW) .... JURA. CRET (yellow)
  - WRANGELLIA - TAKU... (GREENISH) (green)
  - ALEXANDER... (ORANGE) (orange) Today's subject
  - COAST PLUTONIC (CPC) RED / TRACY ARM (pink)

ALL ACRETED to North America

MOVEMENT ~~????~~ ACCRETED AT LOW PALEOLATITUDES

MOVED NORTH AS A UNIT

ARRIVAL? Latest ~~K~~/Early Tertiary

Correspondence/Notes

COMPARISONS

(SLIDE 2) WRANGELLIA vs ALEXANDER vs TAKU

> Both WRANGELLIA/TAKU... (BOTH)

PALEOZOIC CALC-ALKALINE ISLAND ARC ASSEMBLAGES

OVERLAIN BY

~~CALC-ALKALINE ISLAND ARC ASSEMBLAGE~~

LATE TRIASSIC BASALTS (IMMATURE (ISLAND ARC)

> (BUT) ALEXANDER

THICK PALEOZOIC MIOGEOCLINAL PACKAGE

- PLATFORMAL CARBONATES
- BASINAL CLASTICS
- VOLCANICS

TETHYAN fauna

(?) FRAGMENT OF CONTINENTAL MARGIN

... BROKEN OFF ... CALIFORNIA?

- OVERLAIN BY LATE TRIASSIC MAFIC VOLCS (BUT)

in Alexander Terrane are more ALKALINE + YOUNGER (BACK ARC BASIN?)

> OVERLAP

CONTINENTAL VOLCS AND FLYSCH ... GRAVINA-NUTZOTEN

> PLUTONS - cut all Three -

of Jurassic Cretaceous + Tertiary age

> THE TALK FOCUSSES ON THE TRIASSIC ROCKS

(BUT) ~~A~~ CONSIDERS THE DIFFERENCES IN THE

PALEOZOIC BASEMENT.

Slide 2 **TECTONOSTRATIGRAPHIC RELATIONSHIPS**

This slide summarizes the relationships between the Wrangellia, Alexander and Taku terranes in NW B.C. and SE Alaska. The Wrangellia and Taku terranes are very similar and are comprised of a Paleozoic calc-alkaline island arc assemblage that is overlain by Late Triassic basalts. The Alexander terrane on the other hand is comprised of a thick paleozoic miogeoclinal section consisting of platformal carbonates and basinal clastic rocks. These rocks may be a ripped off fragment of the continental margin that originated as far south as California. The Paleozoic rocks of the Alexander Terranes are also overlain by Late Triassic mafic volcanics and sediments but as we shall point out in this talk, these volcanics are slightly younger and more alkaline in composition than those of the Wrangellia and Taku terranes. All three terranes are overlain by continental calc-alkaline volcanics and flysch of the Gravina-Nutzotin assemblage and are cut by plutons of Jurassic, Cretaceous and Tertiary age. For the rest of this talk we will focus just on the Triassic rocks, keeping in mind the significant difference in Paleozoic stratigraphy between Alexander Terrane and the Taku and Wrangell terranes.

SLIDE 3 TRIASSIC STRATIGRAPHY

This slide illustrates the differences in Triassic stratigraphy between Alexander Terrane and the adjacent Wrangellia and Taku Terranes. The main points I want to stress here are that;

1. Alexander basalts are Norian rather than Carnian in age and are therefore younger than those of the Wrangellia and Taku terranes;

2. A sedimentary basin preceded eruption of Late Triassic basalts in the Alexander Terrane and was in part contemporaneous with basalt volcanism in the Wrangellia and Taku terranes.

3. Triassic volcanics of the Wrangellia and Taku Terranes are tholeiitic basalts with no felsic component whereas those of the Alexander terrane include both calcalkaline basalt and rhyolite i.e. a bimodal volcanic assemblage.

4. The Wrangellia and Alexander terranes may have been one terrane in Triassic time and were subsequently moved outboard of the Taku terrane by movement along a major strike-slip fault in Cretaceous or Tertiary time. If this is true Late Triassic volcanism moved eastward and became more calc alkaline with time, a relationship commonly observed above subduction zones in the young volcanic arcs of the SW Pacific.

(1) ALEXANDER basalts NORIAN
- OTHERS - KARNIAN → NORIAN

(2) ALEXANDER - seds first then basalts
- others .. partly contemporaneous with Alexander sedimentation

(3) Alexander
- Bi-modal (felsic component) - orange
- calc alkaline basalt
- Others ... Tholeitic

(4) WRANGELLIA/ALEXANDER

- TOGETHER BY TRIASSIC TIME
- STRIKE SLIP MOVEMENT IN CRET AND TERTIARY MOVED ALEXANDER 'OUTBOARD' OF TAKU (WHICH IS REALLY A PIECE OF WRANGELLIA)
- THEREFORE ~~VOLCANIC~~ TRIASSIC VOLCANISM MOVED EASTWARD AND CHANGED FROM THOLEIITIC TO CALC-ALKALINE WITH TIME.
- SIMILAR RELATIONSHIPS ARE SEEN IN MODERN ARCS IN SW PACIFIC.

SLIDE 4 TRIASSIC STRATIGRAPHY OF THE ALEXANDER TERRANE

FOCUS IN ON TRIASSIC STRATIG IN ALEXANDER Terrane
• SLIDE SHOWS
• 3 AREAS
- WINDY CRAGGY NW BC
- Glacier Creek BC/Alaska Brdry
- SE Alaska

Now we are going to focus on the Triassic stratigraphy within the Alexander Terrane. This slide shows Triassic stratigraphic columns for three separate areas within the Alexander Terrane - the Windy Craggy area in Northwest B.C., the Glacier Creek area which straddles the B.C.-Alaska boundary and Southeast Alaska. As you can see the stratigraphic successions are all very similar and begin with basinal calcareous siltstones and argillite of turbidite origin grading up section into increasing numbers of submarine basalt flows and associated diorite sills. The upper part of the Triassic section is characterized by a thick pile of pillow basalt with little or no sedimentary component.

Felsic metavolcanics also occur in the Glacier Creek and Southeast Alaska areas but are not known in the Windy Craggy area.

Massive sulphide deposits are associated with both mafic and felsic volcanics.

The ages of these rocks has been established by conodont biostratigraphy and macrofossils. The Triassic rocks unconformably overlie Paleozoic strata and in southeast Alaska

~~Alaska~~ there is a well developed erosional conglomerate at the base of the Triassic section.

see slide

Alexander
Ʀ volcs
..in fault
bounded areas -
? originally rift troughs
along a back-arc
transcurrent fault
system.

~~An important feature regarding the distribution of Late Triassic volcanics in the Alexander Terrane is that they appear to be restricted to rectilinear fault bounded areas which may have originally been rift troughs along a back arc transcurrent fault system~~

SLIDE 5 MASSIVE SULPHIDE DEPOSITS - ALEXANDER TERRANE

Now lets look at the types of massive sulphide deposits that are hosted by Late Triassic volcanics of the Alexander Terrane.

These can be subdivided into three types

1. Cu-Co+/-Au+/-Zn massive pyrite and pyrrhotite deposits hosted by chlorite altered basalts and sediments. The best example of this type is Windy Craggy. This is a world class massive sulphide deposit with reserves in excess of 300 million tonnes grading 1.5 percent copper and .08 percent cobalt. Gold rich zones occur in the footwall of the massive sulphide deposit. Geddes Resources has recently completed an 1800 m adit and exploration drift under the deposit. Underground drilling is currently in progress.

2. Polymetallic massive sulphide deposits hosted by quartz-mica-carbonate-mariposite altered phyllites in a mafic volcanic section The best example of this type is Greens Creek which is scheduled to go into production in 1989 with reserves of 3.5 million tonnes grading .18 opt Au, 23.8 opt Ag, 3.9 percent Pb, 9.7 percent Zn. (There is no definitive age for this deposit and there is an outside possibility that it is older than Triassic.)

3. Barite+/-massive sulphide deposits hosted by quartz-sericite altered phyllites in a mafic volcanic section. The phyllites are probably altered felsic volcanics as inicated by their geochemistry. The best example of this type of deposit is Glacier Creek which is a bedded barite deposit with Pb and Zn rich zones..

(1) Cu-Co ± Au ± Zn
massive py pyrrho
Host chlorite altered basalts
WINDY CRAGGY
300 MT 1.5% Cu
0.08% Co
Gold zones in FW

(2) Polymetallic M/s's
Host Qtz Mica Carbonate mariposite altered phyllites in mafic volcs.
GREENS CREEK

(3) →

Now lets take a closer look at some of these deposits.

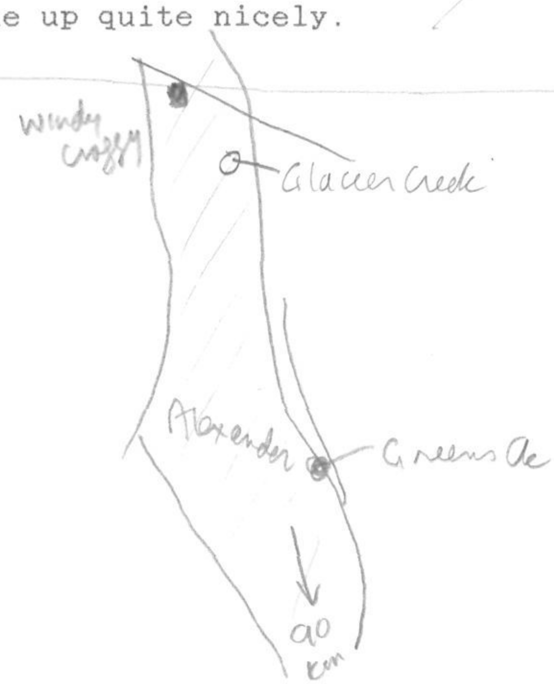
SLIDE 6 LOCATION OF MASSIVE SULPHIDE DEPOSITS IN THE ALEXANDER TERRANE.

This slide again shows the distribution of terranes in NW B.C. and SE Alaska and the location of massive sulphide occurrences. Black squares are MS deposits associated with chlorite altered basalts, green circles are deposits related to quartz-sericite altered volcanics, the so called felsic association.

Windy Craggy Top left

Point out location of Windy Craggy, Glacier Creek and Greens Creek.

Note the Chatham Strait fault offsets the Alexander Terrane with 90 km of right lateral movement.When restored to its original position the Glacier Creek and Greens Creek mineral districts line up quite nicely.



THE COMPANY WAS DRILLING ON THIS FACE LAST SUMMER!

SLIDE 7 SCENIC VIEW OF WINDY CRAGGY

The first deposit we will look at is Windy Craggy. The deposit is located under the cirque glacier in this photo. The deposit is mainly massive pyrrhotite or pyrite with an average copper grade of 1.5 percent and cobalt grade of .08 percent. Reserves are greater than 300 million tonnes. There is gold enriched zone in the footwall which is the current exploration target.

SLIDE 8

The massive sulphide has been traced for over 2000 metres and is up to 100 metres thick in places. It is tightly folded and plunges to the NW. Host rocks are chlorite altered basalts with minor tuff and cherty exhalite. Calcareous sediments and tuffs overlie the deposit. Numerous diorite sills occur in the stratigraphic footwall section and A well developed stringer zone underlies ~~the deposit~~ it.

(continued)

SLIDE 8 1600 METRE LEVEL GEOLOGY, WINDY CRAGGY

This slide was borrowed from John Gammon and shows the 1600 metre level geology as determined by surface drilling. The massive sulphide zone is coloured red, altered basalts are various shades of green and cherty exhalite is ~~coloured~~ maroon.

SLIDE 9 DRILL SECTION THROUGH WINDY CRAGGY

syncline

This drill section illustrates the tightly folded nature of the Windy Craggy ore body which is coloured red. The gold enriched zone is coloured yellow and as you can see is located in the footwall of the massive sulphide body. Best intersection was 12.6 grams per metric tonne over 36 metres. Footwall basalts are coloured in dark green. These rocks are intensely chloritized and cut by stringer sulphides. Whole rock geochemistry indicates these rocks are strongly depleted in Na, K, Ca, Mg, Ba, and Si.

SLIDE 10 DRILL CORE SAMPLE FROM WINDY CRAGGY

This is a typical sample of fine grained massive pyrrhotite and chalcopyrite from the core of the Windy Craggy massive sulphide body. This grades into massive coarse grained pyrite and chalcopyrite in the central part of the body and farther to the northwest there are local concentrations of sphalerite.

SLIDE 11 CHERTY EXHALITE WITH PYRRHOTITE STRINGERS

This is a typical sample from the cherty exhalite zone that underlies the massive sulphide body. These cherty rocks are interbedded with chlorite altered basalts and are cut by stringers of pyrrhotite.

SLIDE 12 RIME OUTCROP

Schroeter

Away from Windy Craggy there are other small massive sulphide lenses hosted by calcareous siltstones beds that are sandwiched between massive altered basalt flows. This particular showing is called the RIME. LAST SUMMER St. Joe's drilled a hole through a glacier located a few hundred metres north of this showing and intersected massive sulphide under 1200 feet of ice.

SLIDE 13 SAMPLE FROM THE RIME

This is a sample of banded pyrrhotite mixed with carbonate from the Rime showing. The interesting thing about this sample is its gold content. This particular sample assay nearly 2 ounces per ton Au. The sulphide occurrences associated with chlorite altered basalts in the Windy Craggy area seem to be characterized by their high gold and cobalt contents.

SLIDE 14 VIEW OF THE GLACIER CREEK DEPOSIT

Now we are going to shift our attention to the Glacier Creek deposit of Alaska which is an example of ~~our~~ a barite-sulphide type of deposit.

~~This is a view of the Glacier Creek deposit.~~ The light coloured zone is quartz-sericite phyllite. Overlying and underlying rocks are massive basalts. A bedded barite deposit occurs within the quartz-sericite phyllite zone and within the barite are lenses of massive sphalerite and galena. Precious metal content is low. Norian age conodonts have been extracted from a thin siltstone bed in the hangingwall section.

SLIDE 15 SCHEMATIC CROSS SECTION OF THE GLACIER CREEK DEPOSIT

This slide is a schematic cross section through the Glacier Creek deposit showing the quartz-sericite schist sandwiched between massive basalt and dipping to the NE. The barite-sulphide zone is coloured red.

The quartz-sericite schist is probably an extrusive rock of rhyolitic composition. Rare earth analyses of samples from this occurrence show a strong Europium depletion suggesting the rocks were formed by magmatic fractionation involving separation of a feldspar phase. Similar felsic metavolcanics occur in SE Alaska and are probably part of a Late Triassic bimodal volcanic event.

SLIDE 16 GREENS CREEK CROSS SECTION

The next deposit type we are going to look at is the polymetallic massive sulphide. These deposits, like Glacier Creek also occur in felsic metavolcanics but in some cases the felsic nature of these rocks may be due to alteration.

The best example of this type of deposit is Greens Creek. Unfortunately the age of this deposit is as yet unknown but it seems likely that it is Late Triassic in age based on lithologic and stratigraphic similarity with other known Late Triassic occurrences. Reserves at Greens Creek, which is scheduled to go into production in 1989 are 3.5 million tons grading .18 opt (ounces/ton) Au,23.8 opt (ounces/ton) Ag,3.9 percent Pb,9.7 percent Zn. When in production it will be the largest silver producer in the U.S.

This slide shows a schematic cross section through the deposit. The deposit is overturned The stratigraphic footwall rocks coloured in cream are quartz-sericite-carbonate-mariposite altered metavolcanics. The presence of Cr micas and TiO2 contents greater than 1 percent suggests they were originally basalts and not rhyolites as originally thought. The stratigraphic hangingwall of the deposit ~~is~~ consists ~~comprised~~ of argillite and greywacke.

SLIDE 17 UNDERGROUND PHOTO OF GREENS CREEK ORE

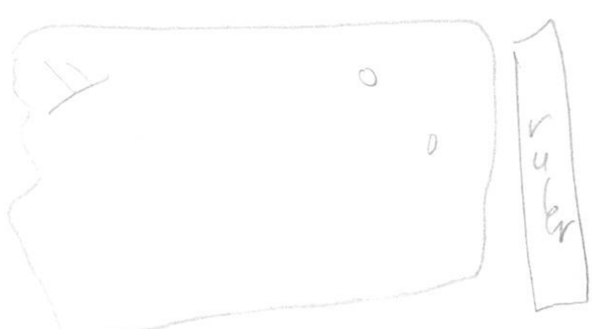
This is a photo taken underground at Greens Creek showing the massive sulphide zone and its contact with stratigraphic hangingwall argillites (overturned section). Three types of ore from top to bottom of the photo are white ore which is recrystallized with abundant quartz, carbonate and barite veins, black ore which is massive sphalerite and galena with high ~~granite~~ graphite content and massive ore (yellow in photo) which is mainly pyrite with pale sphalerite, galena, chalcopyrite, tetrahedrite/tennantite, and acanthite.

Don's Talk

SLIDE 18 FELSIC BASALT SAMPLE

Now that we have looked at the massive sulphide deposit types of the Alexander Terrane lets now examine the nature of the rocks hosting these deposits. First before discussing the chemistry of the basalts we should look at a few samples to get a feeling for what these rocks look like and some of the problems in sampling for geochemical purposes.

This first sample is very light coloured and one might be inclined to map this as a dacite. However, chemically this rock is a basalt, the light colouration is probably due to alteration or weathering although petrographically and chemically this rock is indistinguishable from much darker basaltic rocks. In fact it is relatively fresh and its lower chlorite content might be the reson for its lighter colour.



drill core
ruler

SLIDE 19 SAMPLE OF CARBONATE ALTERED FLOW

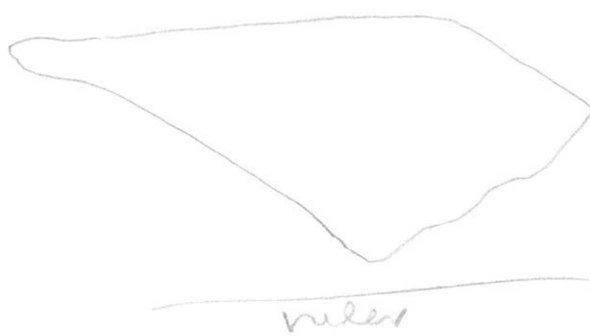
This is a sample of a carbonate altered flow. This type of alteration is common in the hangingwall of the Windy Craggy deposit. CaO contents can be as high as 35 percent. These rocks are useless for major oxide analyses but their immobile element compositions are usually stable. Volume changes due to alteration must be taken into consideration however

SLIDE 20 SAMPLE OF CHLORITE ALTERED DIORITE SILL

This is a sample of a chlorite altered diorite sill from the footwall sequence at Windy Craggy where such sills are quite abundant. Chemically these sills are indentical to basalt flows in the Triassic section. It is assumed the sills are comagmatic. We are currently processing samples for U-Pb dating in an attempt to confirm this relationship. The sills may have been the heat source required to drive the huge hydrothermal system that generated the Windy Craggy massive sulphide deposit.

SLIDE 21 SAMPLE OF INTENSELY CHLORITIZED BASALT

This sample is from the footwall of the Windy Craggy deposit and is an intensely chloritized basalt. Regionally there is low greenschist facies metamorphism and chlorite and epidote alteration is very common. Again, this makes sampling for whole rock geochemistry very difficult if one is restricted to using major oxides.



SLIDE 22 SAMPLE OF AMYGDALOIDAL BASALT

Another common sampling problem is the presence of carbonate and zeolite filled amygdules. Care must be taken not to include such samples in the suite of rocks used for major oxide analyses.

SLIDE 23 SAMPLE OF BANDED ARGILLITE

This is a sample of banded and folded argillite, typical of the thin sedimentary interbeds found in the predominantly basalt succession. Such beds are incompetent relative to overlying and underlying massive basalt flows and are typically intensely folded and sheared. The more calcareous beds have yielded Norian age conodonts (i.d. by Mike Orchard, GSC Vancouver).

SLIDE 24 AFM DIAGRAM

Now lets look at the chemistry of basalts from the Alexander terrane. In each plot notice the range of compositions for Triassic basalts from the Wrangellia and Taku terranes.

In this AFM diagram only the least altered samples from the Windy Craggy area are plotted. Note that most of the points plot in the calcalkaline field whereas those of the Wrangellia and Taku terranes plot in the tholeiitic field.

SLIDE 25 ALKALIES SILICA DIAGRAM

Another classic diagram used by early workers in island arc terranes is the Alkalies-silica diagram. Again only the least altered samples are plotted and most of these plot in the calcalkaline to alkaline fields.

SLIDE 26 Al_2O_3 VS. NORMATIVE PLAGIOCLASE

Another commonly used plot based on major oxide compositions is the Al_2O_3 vs. normative plagioclase plot. Again the results are similar to the two previous plots - most of the Windy Craggy basalts plot in the calc-alkaline field, those of Wrangellia and the Taku terrane plot in the tholeiitic field.

SLIDE 27 MGO-FEO-AL2O3 TERNARY PLOT

This plot uses the major oxides MgO, FeO and Al2O3 to determine tectonic environment. Again, only relatively unaltered samples are plotted. The Alexander terrane samples cluster within the Orogenic field in this diagram.

SLIDE 28 LOG CR VS. LOG TI

A disadvantage of using major oxides to determine tectonic environment is the fact that major oxides are relatively mobile and therefore influenced by alteration effects. However, the immobile elements can be used even for altered rocks. A popular plot is the Log Cr versus Log Ti diagram. Using this plot samples from the Alexander Terrane plot in the Island Arc basalt field whereas those of the Wrangellia and Taku terranes plot in the MORB or tholeiitic field. These results are consistent with those determined using major oxide analyses. Note the consistent separation of the older Triassic basalts of adjacent terranes from those of the Alexander terrane.

SLIDE 29 ZR VERSUS TI

Another popular plot using immobile elements is Zr versus Ti. Although only a few points are shown on this diagram, many more analyses have been completed since this slide was made up and these new results confirm a calc-alkaline basalt trend. This trend is quite distinct from the Wrangellia-Taku trend which tends toward higher Ti contents with increasing Zr content.

SLIDE 30 RARE EARTH PLOT

Rare earth elements are also useful in distinguishing different volcanic types. A characteristic of the Alexander basalts is a trend toward light rare earth enrichment as shown in this chondrite normalized rare earth diagram. This pattern is distinct from the flatter rare earth trends for Wrangellia-Taku basalts and the light rare earth depletion characteristic of MORB´s. The light rare earth concentrations are consistent with the calc-alkaline to alkaline compositions of the Alexander basalts. Note also the more felsic volcanics of the Alexander terrane have a Europium depletion suggesting these rocks have formed through magmatic fractionation processes.

alexander - orange + red.

SLIDE 31 SUBDUCTION MODEL

No talk would be complete without a genetic model or models. First of all though lets summarize what we know about the Late Triassic volcanics of the Alexander Terrane and their contained massive sulphide deposits. These are the constraints we must put on any model.

1. A sedimentary basin developed in early Norian time and was filled by calcareous turbidite detritus derived from exposed landmasses in the area.

2. This basin developed on a thick section of miogeoclinal carbonates and clastics of Paleozoic age; i.e. continenatal crust *not* oceanic crust.

3. Eruption of basalt began within the basin in Late Norian time and was accompanied by injection of subvolcanic sills and deposition of cherty exhalite.

4. Amount of basaltic magma erupted in the basin increased with time culminating in a build up of over 1000 metres of pillow lava in Late Norian time.

5. *Massive sulphide deposits were formed by exhalative* processes within the basin prior to the major outpouring of basaltic magma.

red BLIP

6 Felsic volcanics are also present indicating a bimodal volcanic suite. The felsic volcanics are volumetrically minor compared to basalts.

7. The Late Triassic volcanics are calc-alkaline to alkaline in composition rather than tholeiitic.

The model that seems to best fit the data available is that of a rift trough developed within a back arc basin setting such as shown in this model. Wrangellia basalts would have been an early tholeiitic component erupted in an island arc chain and the more calc-alkaline rocks of the Alexander terrane were erupted in a back arc basin in board from the arc. A progressive enrichment in alkalies from arc to back arc would reflect an eastward shift in the point of partial melting along the subduction zone with time.

SLIDE 32 GUAYMAS BASIN MODEL

An alternative model would be the present day Guaymas basin scenario. Here rift troughs and short lived spreading centers have formed as steps in a major transcurrent fault system in the Gulf of California. The rift trough is the site of eruption of basalt and injection of subvolcanic sills into wet, basinal sediments. Accompanying sedimentation rates are high and the volcanic sequence has high sedimentary component. Massive sulphide deposits form on the seafloor near hydrothermal vents. These vents are typically located above or near a subvolcanic sill that has been injected into the poorly consolidated and wet sediments. The sills provide heat to drive the hydrothermal system. The Guaymas basin is floored by thick continental crust and basalts erupted in the basin tend to be enriched in alkalies and rare earth´s perhaps due to crustal contamination of magma. Tholeiitic composition have also been noted in the Guaymas basin.If spreading is long enough lived then some new crust with oceanic affinities may form within the rift trough but in most cases it appears that spreading centers tend to migrate to new positions along the transcurrent fault system and little new oceanic crust is actually generated.

SLIDE 33 GENETIC MODEL

Finally then this slide illustrates a possible model for Late Triassic basalts and massive sulphide deposits of the Alexander Terrane. In this model the basalts are restricted to fault bounded rift troughs developed within a back arc basin. Attenuation of the crust is accompanied by partial melting of continental material and generation of alkali enriched basaltic magma through contamination. Sills and dykes are injected into turbiditic sediments and generate convective hydrothermal systems that ultimately result in the formation of massive sulphide deposits on the seafloor. These hydrothermal systems have effectively transported and concentrated gold and silver.

The fact that the Late Triassic volcanics of the Alexander terrane are not well explored or mapped and that the deposits that have been discovered to date are very large and economically significant because of their gold and silver content ~~suggests that the~~ indicates The ~~high~~ HIGH mineral potential ~~of~~ for this part of B.C. and Southeast Alaska ~~is very high indeed~~.