PROCEEDINGS OF THE TWENTY-EIGHTH ANNUAL KECK RESEARCH SYMPOSIUM IN GEOLOGY

April 2015
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KECK GEOLOGY CONSORTIUM
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ZIRCON FISSION TRACK AGES OF THE ORCA GROUP ON HINCHINBROOK ISLAND, ALASKA

EILEEN ALEXANDRA ALEJOS, Union College
Research Advisor: John I. Garver

INTRODUCTION

A trench-ridge triple junction, created by the Kula, Farallon, and Pacific plates, formed the accretionary complex of the Chugach-Prince William terrane in Alaska. The terrane accreted onto the plate margin from the Cretaceous to the Paleocene (Garver and Davidson, 2014). The Border Ranges fault system separates these terranes from inboard rocks of Wrangellia, and it may have allowed northward translation of the terrane since the Eocene (Cowan, 2003). This hypothetical translation of the Orca occurred while they were deposited, and metamorphosed. This study investigates the cooling history of the Orca Group in eastern Prince William Sound using zircon fission track analysis, and it builds on previous work in this area (Milde, 2011; Izykowski, 2011; Carlson, 2012).

BACKGROUND

The Chugach/ Prince William Terrane

The accretionary complex of the Chugach-Prince William terrane (CPW) in Alaska is inferred to have been formed along the continental margin through the accumulation of turbidites (Plafker et al., 1994). The terrane accreted onto the plate margin from the Cretaceous to the Paleocene (Garver and Davidson, 2014). The CPW terrane is comprised of thick flysch that was deposited in the Maastrichtian to the Paleocene and has since undergone metamorphism (Garver and Davidson, 2014**).** This study works to understand the provenance and thermal history of the CPW through the use of ZFT analysis and reconstruction of it thermal and tectonic events.

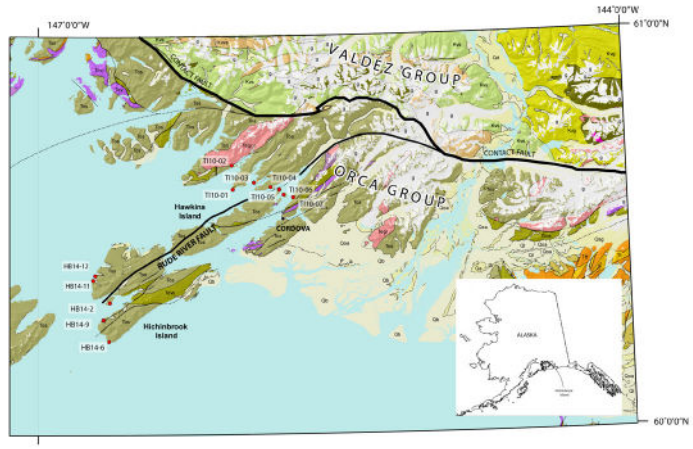

Figure 1. Area of study on Hinchinbrook Island, Alaska. Sample sites for this study are located on Hinchinbrook Island while sample sites from Izykowski, 2011 are located near Cordova. The Rude River Fault is labeled in bold.

Orca Group

The Orca Group is located in the Prince William Sound (PWS) region and is composed of thick, metamorphosed flysch sediments, turbidites, sandstones, siltstones, and tholeitic volcanic rocks (Winkler, 1976: Plafker et al., 1994: Figure 1). While the Orca Group contains imbricated ophiolites and volcanic rocks its primary units are made up of low-grade metamorphosed turbidites. According to paleontologic and radiometric data, the Orca Groups is Paleocene to Early Eocene in age and more recent data suggests that the Orca could be late Eocene or early Oligocene (Plafker, 1985; Plafker et al., 1994; Garver and Davidson, 2014). Previous studies suggest that in the eastern PWS, dextral strike slip faulting has resulted in thermal discontinuities (Izykowski, 2011). The cooling ages of the Orca Group determined

through detrital zircon fission track analysis help to better understand the thermal events that occurred along the Rude River Fault on Hinchinbrook Island.

Recent ZFT Studies

Several recent studies have used ZFT dating to understand the thermal history of the CPW terrane. In eastern PWS, sandstones from the Orca Group were collected along a transect from Sheep Bay to Cordova (Izykowski, 2011). In this study, samples were collected along the Rude River Fault, a dextral strike-slip fault. The ZFT ages show that west of the Rude River fault, samples have similar cooling ages of about ~49-50 Ma and older populations at ~79 Ma and older (Izykowski, 2011). However, samples east of the Rude River Fault have a young population made of a small fraction of grains with cooling ages of ~31 Ma, which is younger than the young population of ages west of the fault (Izykowski, 2011). This study by Izykowski (2011) is most closely related with this recent study (this work) of deformed turbidites collected from part of a transect along Hinchinbrook Island. The Rude River Fault shows distinct difference of old and young zircon populations and their annealing temperatures across the Rude River Fault.

Slightly to the north, samples from the Valdez Group in the Chugach terrane were dated to understand the thermochronology of sandstone samples (Milde, 2011). This study used ZFT dating and track lengths to better understand the grain-age distribution of the samples. Grain age- distribution and track length shows that all of the samples were fully reset at ~38 Ma and show another minor population around ~51 Ma (Milde, 2011). This finding is consistent with pervious studies that suggest that all zircon grains will most likely be reset and fully annealed at ~ 300-350° C (Milde, 2011).

Far to the east on Baranof Island, a transect was collected adjacent to the 48-50 Ma Crawfish Inlet pluton that intrudes the Baranof Schist (Kaminski, 2013). In this study zircon, fission track dating determined that the Eocene post- intrusive cooling occurred after a significant metamorphic event of the Baranof Schist at ~48-50 Ma (Kaminski, 2014). There are two major age populations that reflect cooling at ~42 and ~30 Ma which is comparable to the cooling history of the Leech River Schist (on Vancouver Island) and Chugach metamorphic complex (Kaminski, 2014). It is possible that the units accreted (Leech River Schist, Chugach metamorphic complex, and Vancouver Island) as a belt and were metamorphosed in order when the slab of the Kula and Farallon plates passed (Kaminski, 2014). These units were translated northward after metamorphism occurred, based on paleomagnetic data however the Leech River Schist did not move (Cowan, 2003; Kaminski, 2014).

In western Prince William Sound, a ZFT transect from the contact fault to Montague Island was conducted (Carlson, 2012). In this study 12 sandstones and one plutonic sample show thermal discontinuity on the Montague Straight fault. Samples inboard of the fault show young reset ages indicating formation before their deposition (Carlson, 2012). This heterogeneous cooling history shows three distinct cooling ages; ~50 Ma and ~38 Ma caused by plutonic intrusions and activity at ~25-30 Ma inferred to be caused by the collision of the Yakutat Plate (Carlson, 2012). These fission track ages suggest that the Orca Group found on Montague Island was likely affected by dextral strike slip faulting (Carlson, 2012).

Far to the west but still in the CPW, on Nagai Island (Shumagins), a ZFT transect was done on rocks that are intruded by the 60 Ma Nagai pluton (DeLuca, 2012). Samples from previous projects on Kodiak Island from the Narrow Cape Formation, the Ghost Rocks, and the Kodiak Formation were also analyzed in this study. These samples revealed three distinct cooling age patterns: a) Fully Reset grains with a primary peak at ~44-53 Ma likely represents the thermal events that occurred with the Sanak Baranoff belt pluton (62 Ma); b) a Partially Reset suite has a primary age at ~45-58 Ma and contains grains that are representative of the thermal event at 62 Ma, the provenance, and/or exhumation; c) an Unreset suite with a young population at ~71-72 Ma represents the cooling ages of source rocks (DeLuca, 2012).

Fission Track Analysis

Zircon, $ZrSiO_4$, is a neosilicate that occurs in coarse-grained sedimentary rocks and is an essential mineral for the study of sediment provenance and the

development of mountain belts (Bernet and Garver, 2005). Zircon is resistant to weathering processes so it retains information about the age and thermal history of source rocks (Bernet and Garver, 2005). Fission track dating allows us to determine age and timing of thermal events in sandstones because detrital zircon record the thermal history of the rocks (Bernet and Garver, 2005).

METHODS

Samples in this study were collected from marine turbidite sequences along the coastal exposures of eastern PWS (Fig. 1). These samples were chosen because of their distribution on Hinchinbrook Island and because they were coarse-grained sedimentary rocks, thus zircon bearing. These rocks were medium to coarse-grained sandstones taken from exposed outcrops of the Orca Group. The outcrops and collected units were described, sketched, and their Global Positioning System (GPS) was recorded.

Zircon Extraction

Whole rock samples (2-4 kg) were crushed using a Chipmunk crusher and were then pulverized by a Bico Braun® pulverizer. The resulting fine-grained samples were separated by density using a Roger's Table. The Rogers Table sorted the rock flour into four containers based on density. After these samples were separated by density they were dried in the extraction lab over overnight and sieved using a 300 µm mesh sieve. The final dried sieved samples (~200 mL) were further separated by a heavy liquid separation using a Tetrabromethane. The sample was the separated by the Frantz magnetic separator, which removes any magnetic minerals, and finally separated using Diiodomethane.

Sample preparation

Zircon grains were mounted of Teflon® squares and two mounts were made for every sample. The Fish Canyon Tuff and Peach Springs Tuff were used as standards because their cooling ages are known. The samples were then polished in a Buehler Automet 200 Powerhead® and Eco Met® 300 Variable Speed Grinder. A 9 µm and 1 µm diamond suspension solution were used for polishing. The mounts were polished with a Micropolish II aluminum oxide slurry which was a 0.3 µm polish solution. Polished samples were then placed in a NaOH-KOH solution in an etching oven for 16- 24 hours, which etches the samples revealing the spontaneous fission tracks in the zircon grains as a result of uranium decay. Mica was perfectly cleaved then it was matched and attached to the Teflon samples. These samples, along with the standards and three Corning CN-5 glass dosimeters were all fit to mica in order to prep them to be irradiated. These samples were sent to the USGS nuclear reactor to be irradiated in Denver, Colorado (Irradiation U55Z, September 2014). The mica was etched in hydrofluoric acid for 18 minutes at room temperature (25 °C). The mica rinsed in dilute NaOH, then was cleaned in water, and then ethanol. Once dry the mica and Teflon® mounts were mounted as mirrors on the same glass slide with adhesive.

Counting Fission Tracks

Spontaneous and induced fission tracks are counted using an Olympus BMAX-60 microscope under reflected and transmitted light with a magnification of 1250x. The Zircon grains of the Teflon® mount (left side of the slide) were marked with a CalComp® tablet using FTStage v2.0 software. The grains were analyzed and graded for their quality. Grains with clear tracks of various track densities, no scratches, and properly etched grains were considered to be of a good counting quality. Grains with zonation, large inclusions, little clarity, and uneven uranium density were avoided (Bernet and Garver, 2005). The standard samples, Fish Canyon Tuff and the Peach Springs Tuff were used to determine the zeta calibration factor as calculated by the ZetaMean program. Induced tracks on the mica from the dosimeters were counted was used to calculate neutron fluence. When possible, about forty grains were counted for each unknown sample. The cooling ages produced from ZetaAge were analyzed by BinonFit, which looked at the distribution of ages within each sample. These results were displayed on a probability density plot that illustrates the age clusters and shows cooling age trends within the samples.

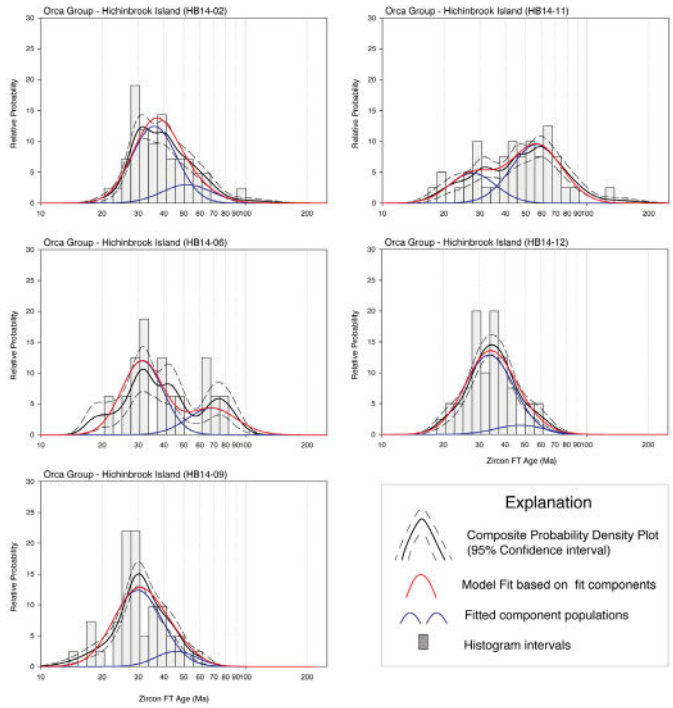

Figure 2. Population density plots for fission track ages of Orca Group samples from Hinchinbrook Island. Samples HB12-02, 06, and 09 are located eastward of the Rude River Fault and samples HB14-11 and 12 lie to the west of the Rude River Fault.

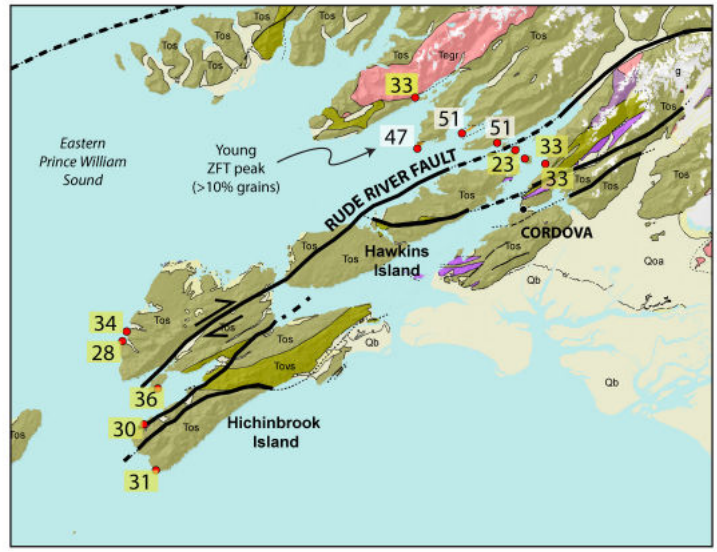

Figure 3. Data of samples from transects of deformed turbidites on Hinchinbrook Island and Cordova that lie eastward and westward of the Rude River Fault. Data near Cordova are from Izykowski, 2011.

RESULTS

A total of five samples were analyzed by ZFT dating (Figure 2). The thermochronology of the deformed turbidites along the Rude River Fault on Hinchinbrook Island was studied through the use of ZFT analysis and at the same time U/Pb dates were used to determine maximum depositional ages (MDA) (results in Grimm, 2015, this volume). Samples east of the fault have large populations of young grains that have been reset at ~30-36 Ma, and some older peaks of ~46-55 Ma. Sample HB14-02, located on Nuchek Island shows that 79% of the grains define a young peak at ~36 Ma. The older peak has an age of 52 Ma that makes up 21% of this sample. Sample HB14-06 from near the abandoned Coast Guard station (SW Hichinbrook), has a young peak at ~31 Ma which is defined by nearly 70% of the grains and an older peak at ~69 Ma defined by only 30% of the grains. HB14-09 is from English Bay and has a young peak of 86% at ~30 Ma and an older peak at ~46 Ma which is defined by 14% of the sample.

Samples west of the fault appear to have populations of older grains with ZFT ages of ~28 Ma and ~57 Ma. Sample HB14-11 is located in Deer Cove and has a younger peak of 32% at 28 Ma Ma and an older peak at 57 Ma represented by 68% of the sample. HB14-12 was also collected in the Deer Cove area has large young peak made of nearly 90% of the grains at 34 Ma and an older peak made up of 10% of the grains at 48 Ma.

DISCUSSION

The Contact fault system in eastern PWS was studied and revealed that there are three distinct litho-tectonic belts that are separated by strike-slip faulting (Bol and Roeske, 1993). This network of strike slip faults resulted in clockwise rotation of blocks in response to dextral shear as seen from the westward shift of structures around the Jack Bay Fault (Bol and Roeske, 1993). Strike slip faults are generated in the forearc regions when oblique subduction occurs and then block rotation occurs from dextral shear on the strike-slip faults, which is what has occurred in eastern Prince William Sound (Bol and Roeske, 1993). Middle Eocene plutons intruded the late Paleocene/ early Eocene Cordova region and interfere with the Contact fault system which shows that displacement, accretion, dextral strike slip faulting, and block rotation in this system probably occurred until ~50 Ma (Bol and Roeske, 1993).

The Chugach-St. Elias orogen in southeastern Alaska was produced by the oblique collision and flat-slab subduction of the Yakutat terrane (Enkelmann et al. 2008). ZFT and UPb dating show the exhumation history resulting from the orogenic development around ~30 Ma (Enkelmann et al. 2008). This exhumation has effected major fault zones and has shifted southward, possibly towards the Contact Fault system (Enkelmann et al. 2008).

In the easternmost part of the CPW terrane, the Crawfish Inlet pluton and the Baranof Schist have a young cooling age and an overall cooling of that area from ~ 42 to 27 Ma (Kaminski, 2014). ZFT ages reveal a slow uniform cooling between 27-39 Ma with two major age populations that could reflect possible thermal events at ~42 and ~35 Ma (Kaminski, 2014). This cooling curve is comparable to the Leech River Schist (to the south) and Chugach metamorphic complex (to the north and west). These metamorphic complexes were effected by metamorphism and then effected by northward strike-slip faulting (Bol et al, 1993 and Kaminski, 2014).

Detrital zircon fission track analysis revealed that there are significant discontinuities in the cooling ages of the deformed turbidites along the Rude River Fault near Cordova (Izykowski, 2011). In eastern PWS on Hinchinbrook the samples have cooling ages younger than the depositional age and multiple populations of grain ages, but the young population appears to be statistically indistinguishable across the study area.

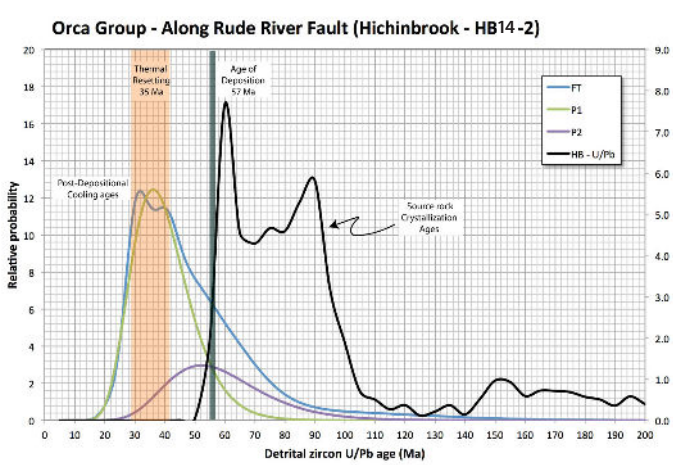

Figure 4. Probability density plot of fission track cooling ages (blue) for HB14-02. Sound cooling age populations are labeled.

This finding is different than that of Izykowski (2011) who studied rocks nearby but on the mainland where there is a discontinuity of cooling ages across the fault.

A probability density plot of fission track cooling ages for sample HB14-02 reveals the coherent cooling age populations (Figure 4). The youngest grains reflect the post- depositional cooling ages. ZFT shows that the grains that range from ~30 Ma to ~40 Ma account for the thermal resetting of grains. The age of deposition is ~ 57 Ma which is based on the U/Pb dating (results in Grimm, 2015, this volume). The source rock crystallization ages are much older and lag ~30 Myr behind the other distinguishable grain populations.

The young populations that are fully reset have been brought up from depth in the accretionary prism. These younger ages reveal that the Rude River Fault experienced slightly different annealing temperatures on the east and west sides which is consistent with previous studies (Izykowski, 2011) (Figure 3). Previous samples from a transect of Orca near Cordova show younger ages to the east of the fault (~23 Ma- 33 Ma) and older ages (~33Ma - 51 Ma) west of the fault (Izykowski, 2011). The older grains have a young ZFT peak that accounts for more than 10% of the grains (Izykowski, 2011). The rocks to the east of the fault have larger young populations (~30-32 Ma) than the populations to the west. It is possible that the east and west blocks of the Rude River fault are effected by strike-slip faulting ~30 Ma which could be related to the movement and initial collision of the Yakutat terrane (Enkelmann et al. 2008).

Previous studies attribute the complex faulting in PWS to the collision of the Yakutat, which collided into the North American Plate by the Pacific Plate. The translation hypothesis suggests that the schists of Baranof Island and those of the Leech River complex are similar in terms of their age, metamorphic processes, and their unique metamorphic mineral assemblages (Cowan, 2003). It is likely that these units coexisted until metamorphism and cooling around 40 Ma. Previous studies also note that the Boarder Range faulting system is responsible for the costal slip and tectonic translation of rocks to southern Alaska during the Tertiary (Cowan, 2003). Previous studies and this study show that the costal rocks in southeastern Alaska cooled ~30 Ma. This cooling along the margin could

have been initiated if strike-slip faulting was onset by the initial subduction of the Yakutat around ~30 Ma. It seems that the westward block of the Rude River Fault was translated by a strike-slip fault and diminished westward.

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