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SYSTEMATICS OF METAMORPHIC MONAZITE AND ITS BEARING ON THE PETROGENESIS OF THE KIGLUAIK GNEISS DOME, SEWARD PENINSULA, AK

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Monazite U-Pb isotopic data from upper-amphibolite-facies orthogneiss, metapelite, and partial-melt pegmatites document a 91 ± 1 Ma age for a high-temperature metamorphic event that overprints an earlier blueschist-facies metamorphism recorded in the mantling schists and gneisses of the granite cored Kigluaik gneiss dome on the Seward Peninsula, Alaska. Zircon U-Pb isotopic data from the compositionally diverse granitoid pluton in the core of the dome indicate an age of 92 ± 2 Ma thus supporting a genetic relationship between Late Cretaceous magmatism and metamorphism.

Monazite dates from orthogneisses range from 96 to 91 Ma, whereas monazite dates from metapelite and pegmatite cluster between 90 and 91 Ma. We interpret the older dates in orthogneiss as reflecting Pb inheritance from their original igneous crystallization at 555 ± 25 Ma as determined from U-Pb analyses of zircon. Monazite from the metapelite and pegmatite instead crystallized initially during Late Cretaceous metamorphism and thus do not record an earlier history. All monazite analyses vary systematically with grain size; 75-150 μm grains are 1-2 m.y. older than 45-75 μm grains.

Field relations together with Nd and Sr isotopic data indicate that the Kigluaik pluton contains a significant mantle derived component. The pluton consists of a ~0.5-1 km biotite granite cap overlying quartz diorite to granodiorite whose root is not exposed. Mafic pillows with crenulate margins indicate mixing of two coeval magmas along the mafic/felsic contact. Geochemical data indicate mixing of mafic magma with an older, crustal source. Combined Nd and Sr isotopic data from the mafic root, the granitic cap, and from a related diabase dike swarm lie on a trend from initial ratios (@ 91 Ma) of $^{87}Sr/^{86}Sr$ = 0.706 to 0.709 and ε_{Nd} = -0.2 to -8.0. Isotopic ratios from the country rocks (calculated for 91 Ma) are $^{87}Sr/^{86}Sr > 0.720$ and $\varepsilon_{Nd} > -8.0$ and lie on the extension of the trend of the analyses from the pluton. Initial ratios from the pluton also correlate with silica content (positively for Sr, negatively for Nd) which would be expected if the magma were incorporating older crustal material. REE plots show mixing between a LREE-enriched source and a source with a flat REE distribution.

The geochronological and geochemical data indicate that the igneous rocks and coeval metamorphism resulted from the emplacement of mantle-derived magmas which provided the heat necessary for upper-amphibolite-facies metamorphism and partial melting during a Late Cretaceous extensional event that post-dated crustal thickening in northern Alaska. The Kigluaik gneiss dome may help understand magmatic processes at the deeper levels of extensional core complexes such as those in the Basin and Range province of the western United States.

CHRONOLOGY OF INTERIOR ALASKAN LOESS-PALEOSOL DEPOSITS BY THERMOLUMINESCENCE

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The thick (25m+) and widespread loess deposits of interior Alaska have interbedded micro and macro fossils, organic beds and paleosols. They thus represent an important source of paleoclimatic and paleoecologic information. However, the chronology of deposition has only recently (1990) been quantified, in a broad sense, using fission-track dating of interbedded tephra beds. We applied thermoluminescence (TL) sediment dating methods to loess near Fairbanks thought to be younger than ~200 ka, to provide a chronology of key deposits for an age range usually inaccessible to other dating methods.

We have ~20 TL preliminary ages (from the fine-silt total-bleach and partial-bleach procedures) for loess and buried soils. More samples are being analyzed. As an age check, we dated loess just above and below the 140±10 ka Old Crow tephra (OCt) at the Birch Hill site, obtaining TL ages of 128±22 ka (1σ) and 144±22 ka respectively. At the Sheep Creek Cut site loess 2 cm above the regionally important Sheep Creek tephra (SCt) gave an age of 184±27 ka, in agreement with TL ages of 191±24 ka and 205±31 ka for loess 2 cm above and 2 cm below (respectively) this ash at the Dawson Cut site. These results support the recent suggestion of Preece that this tephra is older than the OCt. However, at site Eva Creek II loess above and below an ash also correlated to SCt gave ages of 117±19 and 150±28 ka.

At two sites we confirm that the significant erosional unconformity at the top of the Gold Hill Loess corresponds to the time of the Eva Interglacial (Sangamon). At Dawson Cut we obtained loess TL ages of 61±6 ka above and 177±30 ka below the unconformity. At Sheep Creek Cut, loess just below this unconformity gives a TL age of 115±19 ka. We also obtain the first direct ages for two significant buried organic horizons at the Gold Hill 1 site. A 76±10 ka age for a thick organic silt at 11 m depth could represent paleosol development during isotope stage 5a warming. A thick, laterally extensive organic silt at 3 m depth here is dated directly at 29±4 ka. In other parts of interior and northwestern Alaska there are prominent or recognizable "buried soils" in stratigraphically similar positions to our upper "soil", with radiocarbon ages near 30 ka B.P. at one site (Epiguruk), thus suggesting that a regional, late Wisconsin paleoclimatic stratigraphic marker may exist.

At some localities there is evidence that post-depositional reworking or contamination (e.g., via translocation of fine silt through modern rootlet channels) have lowered TL ages. Future TL samples at certain sites would probably need to be excavated from at least 60 cm behind "fresh" section faces.

RESOLVING HIGH PRECISION U/Pb AGES FROM TERTIARY PLUTONS WITH COMPLEX ZIRCON SYSTEMATICS: EXAMPLES FROM SE ALASKA

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Complex zircon systematics due to the combined effects of inherited components and Pb-loss are relatively common in Mesozoic and Tertiary plutonic complexes. Interpreting slightly to strongly discordant conventional zircon data from such samples is difficult since the assumption of either simple Pb-loss or a singular inherited or entrained xenocrystic component necessary for conventional concordia analysis is invalid. In addition, commonly employed air abrasion techniques cannot decipher the effects of both inheritance and Pb-loss. In contrast, step-wise dissolution techniques entailing analysis of sequential partial digestion steps have proven instrumental in resolving useful age information from populations exhibiting complex discordance patterns.

Utility of the partial dissolution technique is exemplified by comparison of conventional and step-wise analyses on relatively low-U (200-500 ppm) zircon populations from two Tertiary plutons in the Coast Mountains batholith, SE Alaska. Conventional analyses on abraded and unabraded fractions of differing size and magnetic properties yield moderately discordant to concordant results defining arrays that clearly indicate the presence of inherited components (Fig. 1). Age interpretations for these samples are limited by the non-linear variation in U/Pb and Pb/Pb ages and uncertainty in the magnitude of Pb-loss suspected from independent evidence (A: 56.5 ± 1.1 Ma assuming *no* Pb-loss; B: 62 ± 3 Ma as reasonable estimate). Partial dissolution experiments tailored to relatively low-U, young zircons produced successive leach steps that define a trajectory of decreasing $^{207}Pb/^{206}Pb$ ages and, with exception of sample B residue, increasing U/Pb ages (Fig. 1). In both cases, the residues are concordant allowing for a Th correction uncertainty of ~1 Ma in the $^{207}Pb/^{206}Pb$ age. Sequential leach steps are inferred to have preferentially removed outer high-U zones susceptible to Pb-loss as well as internal inherited or xenocrystic components. The resilient residues are interpreted to have been comprised of pristine magmatic zircon relatively free of these effects and thereby providing the best estimate of crystallization age for the samples (A: 57.8 ± 0.3 Ma; B = 62.6 ± 0.3 Ma).

We suggest that the step-wise dissolution technique allows resolution of complex zircon systematics and high precision age determinations that are unobtainable with conventional thermal ionization or ion microprobe techniques. Although absolute age estimates for young samples are plagued by decay constant and Th correction uncertainties, this technique will allow resolution of relative emplacement and deformational chronologies for plutonic and metaplutonic complexes.

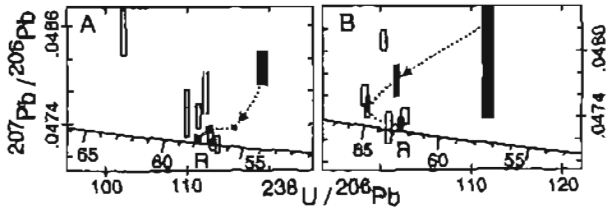

Figure 1. Terra-Wasserburg diagrams showing conventional analyses (open), partial dissolution steps (solid), and trajectory (dotted line) from initial steps to residues (R).

TIMING AND SOURCE OF LODE GOLD IN THE FAIRBANKS DISTRICT, INTERIOR ALASKA

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The Fairbanks Mining District has produced over 7 million ounces of placer gold. Recently two large bulk-mineable vein/stockwork lode deposits have been discovered. The Ryan lode mine contains approximately 1 million ounces of gold grading .08 ounces per ton. It is hosted in greenschist facies schist and in a small granitic porphyritic intrusion. The ore is localized in brittle shear zones. Arsenopyrite is the main accessory mineral. The Fort Knox deposit contains approximately 4 million ounces of gold grading .028 ounces per ton. The deposit consists of stockwork veins and brittle shear zones hosted wholly in a multi-phase granitic porphyritic intrusive. Bismuthinite and tellurobismuthite are the main accessory minerals.

The Ryan lode and Fort Knox yield similar ages. Magmatic ages (U/Pb for zircon, Ar^{40}/Ar^{39} for horneblende and biotite) are 91±1 Ma whereas hydrothermal micas give Ar^{40}/Ar^{39} dates of 89±1 Ma with minor resetting from an early Tertiary heating event.

Fluid inclusions (all secondary) indicate trapping temperatures and pressures of 310°± 15°C and .5-.75 kbar for the Ryan lode and 310°± 15°C and 1-1.5 kbar for Fort Knox. Aplite geobarometry gives pressure estimates of 1-1.5 kbar for intrusive rocks. CO_2 contents are variable and average approximately 13 mole % for the Ryan lode lode and 22 mole % for Fort Knox; methane is a minor contaminant. Salinities are 1-3 wt. % for the Ryan and 3-6 wt. % for Fort Knox. The variable CO_2 content is indicative of minor H_2O-CO_2 immiscibility.

The dating, together with fluid inclusion and aplite geobarometry, indicate that the heat source for the deposits were intrusives emplaced at moderate to shallow depths. The similarity of fluid compositions and dates from both deposits indicate a common fluid genesis.

Fluid compositions and temperatures are similar to 1)secondary inclusions found in some porphyry molybdenum and porphyry tungsten deposits (implied magmatic origin) and 2)primary and secondary inclusions associated with gold districts identified as having a metamorphic fluid source. The high geothermal gradient, porphyry style veining, low methane content, low chlorine content of magmatic biotites, and reduced nature of the plutons presently point to a porphyry-type model with a probable magmatic source for both fluids and gold. This indicates that the fluids commonly found in schist-hosted mesothermal vein districts (low salinity, high CO_2, moderate temperatures) may have either magmatic or metamorphic sources.

Nd, Sr AND Pb ISOTOPIC CONSTRAINTS ON MECHANISMS OF CRUSTAL GROWTH IN THE YUKON-TANANA TERRANE IN YUKON TERRITORY, CANADA, AND EASTERN ALASKA, U.S.A.

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Yukon-Tanana Terrane (YTT) is a large, possibly composite, terrane whose constituent lithotectonic assemblages suggest a mainly continental affinity. Previous geological, geochemical, and U-Pb dating studies suggested that arc magmatism occurred across much of the YTT in latest Devonian to mid-Mississippian and in the central and southeastern parts of the terrane in Late Triassic to Early Jurassic time. These arc assemblages were built on a basement of Early Paleozoic and older passive margin sedimentary rocks. Broadly bimodal volcanic and plutonic rocks of mid-Permian age in western Yukon may be the product of either a more areally restricted intervening phase of arc magmatism or an anorogenic igneous event. Isotopic signatures of each of the Paleozoic to Early Mesozoic igneous suites indicate a marked component of contamination from continental crust. Metaluminous plutonic and related volcanic rocks of the Devonian-Mississippian arc assemblage have $\epsilon_{Nd(T)}$ values of -10 to -13, Sr_i of 0.708-0.712, and feldspar Pb isotopic compositions that plot near the "shale curve" defined for evolution of Pb in strata of the miogeocline of western North America. Strongly peraluminous plutons, also of Devonian-Mississippian age, that were emplaced at deeper crustal levels within YTT have have $\epsilon_{Nd(T)}$ values of -13 to -16, and highly radiogenic Sr_i (0.716-0.730) and feldspar Pb compositions. This plutonic suite may be entirely crustally derived and not directly subduction-related. Both of the Devonian-Mississippian igneous suites contain a trace to strong inherited component of older zircon (average ages 1.7 - 3.1 Ga). Pb isotopic compositions for syngenetic sulfide deposits hosted by the Devonian-Mississippian volcanic arc rocks also fall on or near the "shale curve". The mid-Permian igneous suite has $\epsilon_{Nd(T)}$ values of -5 to -15 and Sr_i of 0.706-0.711, and contains a relatively minor inherited zircon component. Compositions of Pb in feldspars and in sulfides from syngenetic base metal occurrences hosted by the mid-Permian volcanic rocks are slightly less radiogenic than the "shale curve". Available data do not permit distinction between a magmatic arc vs. anorogenic origin for this suite. Early Mesozoic plutonic rocks in YTT are compositionally less evolved than the older igneous suites, have more juvenile Sr_i values (0.704-0.706), and typically contain only a minor component of inherited zircon; however $\epsilon_{Nd(T)}$ values of -1 to -7 indicate significant interaction with older continental crust.

Taken together, the isotopic and other data for the YTT indicate that the terrane is mainly a product of mid-Paleozoic to Early Mesozoic continental arc magmatism. The data are permissive of an origin for YTT as a distal portion of the western edge of North America.

CENOZOIC UPLIFT AND THERMAL HISTORY OF THE NORTH SLOPE FORELAND BASIN, NORTHERN ALASKA AND NORTHWESTERN CANADA

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Results from apatite fission track analyses of Mississippian through Tertiary sedimentary rocks and Devonian granitic rocks from the Alaskan Cordillera of northern Alaska and northwestern Canada, have provided important information about the timing, amount, and rate of uplift experienced within the region. The analyses, together with regional geological observations indicate that several episodes of rapid cooling have occurred in the northern part of the Alaskan Cordillera throughout the Tertiary. Most of these episodes of rapid cooling were due primarily to uplift and erosion, but at least one case, during the Miocene, must have occurred in response to a major regional decrease in the mean annual surface temperature.

The northern part of the Alaskan Cordillera has long been interpreted as a component of a major Jurassic-Cretaceous convergent margin compressional orogen. The northern tectonic elements of this orogen include the North Slope foreland basin, and the Brooks Range fold and thrust belt. The geologic relationships across much of the foreland basin have been complicated by continued advancement of the fold and thrust belt to present time. However, due to poor geologic control, the timing of the deformational events responsible for uplift and erosion during the Tertiary have been constrained, for the most part, only in a relative sense.

Interpretations of apatite fission track analyses, suggest the region studied experienced rapid cooling due to uplift and erosion at various times during the Tertiary. This includes the Big Fish River area of the Mackenzie Delta region in Canada which experienced rapid uplift and erosion during the early Eocene at ~53±4 Ma (all errors reported at ±2σ). Sedimentary and granitic rocks exposed in the northeastern Brooks Range (NEBR) in northeastern Alaska, and along the Phillip Smith Mountains Front to the west of the NEBR, experienced four episodes of rapid uplift and erosion during the Tertiary. These occurred in the middle Paleocene at ~60±4 Ma, in the middle Eocene at ~43±3 Ma, in the early Oligocene at ~34±3 Ma, and in the late Oligocene at ~25±3 Ma. Fission track results from sedimentary rocks collected from both outcrop and subsurface localities along the northern foothills of the Brooks Range west of the Phillip Smith Mountains Front, and throughout the North Slope foreland basin, suggest the entire region experienced two episodes of rapid uplift and erosion, at ~60±4 Ma and ~25±3 Ma.

The interpreted fission track results also suggest that the region experienced a major decrease in the mean annual surface temperature of ~15°C during the Early-to-middle Miocene at some time between ~20-10 Ma. This decrease in mean annual surface temperature has resulted in an equivalent amount of subsurface cooling at shallow depths (less than ~4-5 km), unrelated to either uplift and erosion or a decrease in heat flow.

Therefore, the results suggest that there were two major episodes of deformation which have affected the entire foreland basin in the Tertiary; during the Paleocene at ~60±4 Ma, and during the late Oligocene at ~25±3 Ma. Deformation and resulting uplift and erosion also occurred on the North Slope during the mid-Eocene to mid-Oligocene, at ~43±3 Ma and ~34±3 Ma, but deformation was localised and only affected the NEBR.

THERMOCHRONOLOGIC HISTORY OF THE McKINLEY PLUTON, DENALI NATIONAL PARK, ALASKA

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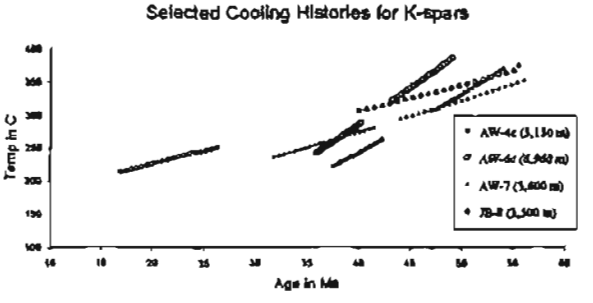
The McKinley pluton is one of the northern-most plutons of the Alaska-Aleutian Range batholith. This biotite-granite intrusion makes up most of the 6,194 m high Mt. McKinley (Denali) massif. Geochemical studies indicate that the entire pluton is homogeneous and was intruded as a single unit. Previous K-Ar and apatite fission-track studies suggest that the pluton has had a protracted cooling/uplift history since its emplacement at ~56 Ma. The great local relief available for sampling makes the McKinley pluton ideal for a thermochronometric study through $^{40}Ar/^{39}Ar$ dating of K-feldspars and biotites. We have conducted detailed step heating experiments on samples collected from a range in elevation of 2,100 to 5,990 m.

Six biotites and one primary white mica have relatively flat age spectra with plateau ages between 55.1 and 55.8 Ma. They show a very slight age/elevation dependence with the lower biotites being younger. These consistent mica ages most likely reflect uniform cooling of the pluton at this time.

Seven K-feldspars samples exhibit saddle-shaped age spectra that vary significantly from each other. High Cl/K values are seen in the first ~5% of gas release in some samples and appear to coincide with old ages (excess argon). Cycled heating experiments carried out on the K-feldspars indicate that they contain multiple diffusion domains that we have modeled using the computer programs of Lovera (1992). From this analysis, a detailed, internally consistent, thermochronologic history spanning ~35 m.y. for the McKinley Pluton emerges. The pluton cooled slowly at rates of 10^0 to 4^0 C/m.y., with the lower samples cooling at the slower rates. The vertical variation of K-feldspar ages records an average uplift rate of 1.3 mm/Ma from 43 Ma to 25 Ma. Thus, the McKinley Pluton reached high levels in the crust by 20 Ma such that even the smallest domains of the K-feldspars do not record the rapid uplift of Mt. McKinley that began at 5 Ma indicated by apatite fission track dating.



Lovera, O. M., 1992, Computer programs to model $^{40}Ar/^{39}Ar$ diffusion data from multidomain samples: Computers and Geosciences, v. 18, p. 789-813.