APATITE AND ZIRCON FISSION-TRACK DATES FROM THE NORTHERN PLOMOSA MOUNTAINS, LA PAZ COUNTY, WEST-CENTRAL ARIZONA

by

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INTRODUCTION

Fission-track thermochronologic data have the potential to reveal aspects of the timing, rate, and style of crustal extension tectonics. Previous fission-track studies in the footwalls of detachment faults in the Basin and Range Province of western North America have found monotonic decreases in apparent fission-track age in the slip direction of the faults (e.g., Fitzgerald and others, 1991; Foster and others, in press). This pattern has been interpreted as recording the time at which progressively deeper parts of the footwalls to the detachments have moved through the annealing zone for fission-tracks in apatite.

In this study we analyzed fission-tracks in apatite and zircon from samples of Proterozoic crystalline rock from a south to north transect across the northern Plomosa Mountains, Arizona (Figure 1). The transect runs from about 100 meters structurally below the Tertiary unconformity (DF90-226) north to the deepest exposed structural levels in the range (DF90-220) beneath the Tertiary Plomosa detachment fault (Scarborough and Meader, 1981). In addition, one sample (DF90-221) is from a detached block of basement in the hanging wall of the Plomosa fault in the northern-most part of the range. The fission-track data from these samples constrain the low temperature (<250°C) thermal history of the northern Plomosa Mountains and have implications for the timing and rate of displacement on the Plomosa detachment. The data also have implications for nature of extension in this range which occupied a position near the breakaway region for detachments in the Whipple tilt domain (Spencer and Reynolds, 1991).

METHODS

Fission-track analysis of samples of crystalline rocks from the northern Plomosa Mountains was undertaken at La Trobe University. Apatites were separated from crushed samples using conventional magnetic and heavy liquid techniques. Apatite grains were mounted in epoxy resin on glass slides, ground and polished to reveal an internal surface and then etched in 5N HNO_3 for 20 seconds at room temperature (22°C) to reveal fossil fission-tracks. Zircon grains were mounted in FEP teflon discs, ground and polished, and their internal surfaces were etched in eutectic KOH-NaOH melt at 230°C for times ranging from 26 to 34 hours. Samples were irradiated in the Australian HIFAR Reactor. Thermal neutron fluences were monitored in muscovite detectors adjacent to discs of NBS glass SRM612 for the apatites and Corning glass U3 for the zircons. Ages were determined using the external detector method with muscovite as the external detector. The mica detectors were etched in 40% HF for 20 minutes at room temperatures to reveal the induced tracks. Apatite and zircon sample mounts were counted at magnifications of 1250x and 1600x, respectively under dry objectives, and only those grain surfaces oriented parallel to the c-axis were counted. Ages were calculated using the zeta calibration method (Hurford and Green, 1983), and errors calculated by the conventional method (Green, 1981). Lengths of horizontal confined fission-tracks were measured in apatite grains oriented approximately parallel to the c-axis using a projection tube and digitizing tablet.

The temperature interval below which fission-track in apatite are effectively stable on geologic time scales is relatively well known from laboratory and natural annealing studies. Above about 120°C fission-tracks in apatite fade almost instantaneously on a geologic time scale and below about 60°C they are effectively stable (Naeser, 1981; Green and others, 1989). The effective closure temperature for fission-tracks in zircon is less well understood but is around 200° ± 50°C (Harrison and others, 1979; Hurford, 1986).

RESULTS AND INTERPRETATION

Zircon and apatite fission-track results for eight samples from the northern Plomosa Mountains are given in Table 1 and sample location data is provided in Figure 1. As mentioned above, seven of the samples are from a north-south transect across the footwall of the Plomosa detachment fault; these are samples DF90- 220, -222, -223, -224, -225, -226, and -227 (Figure 1). Sample DF90-221 is from a hanging wall block at the northern end of the range. This hanging wall block is thought to have been displaced some 13 kilometers to the northeast, relative to footwall rocks, by the Plomosa fault (Spencer and Reynolds, 1991). A plot of the apparent zircon and apatite fission-track ages with distance along a projection in the slip direction (N45°E, Spencer and Reynolds, 1991) of the Plomosa fault is given in Figure 2. For the samples collected from the footwall block the distance along the profile to the northeast is also the direction of increasing paleodepth prior to faulting. Sample DF90-226 was collected about 100 meters below the Tertiary unconformity while DF90-220 was collected from a paleodepth of >10 kilometers, assuming that the Plomosa Mountains footwall is an unbroken block uniformly tilted to the southwest about 45° (Scarborough and Meader, 1989; Spencer and Reynolds, 1991).

The four zircon fission-track ages from the footwall samples range from 23 ± 2 Ma to 17 ± 3 Ma (Table 1) and show a general decrease in age from south to north (Figures 1, 2). The zircon fission-track age of the sample from the hanging wall block is 55 ± 5 Ma. The apatite fission-track ages for all of the samples, including the hanging wall block, range from 23 ± 3 Ma to 14 ± 1 Ma, and like the zircon results, exhibit a decrease in age from south to north (Figure 2). Mean lengths of confined fission-tracks for five of the apatite samples range from 13.3 ± 0.5 μm to 14.1 ± 0.2 μm. However, in only two of the samples (DF90-224 and -225) were enough tracks observed and measured for the mean length to be statistically valid. These two samples both gave mean track lengths of ~14 μm and narrow standard deviations of 1.4 μm and 1.5 μm. The relatively small number of confined tracks in these samples is because of their geologically young fission-track age, and thus low fossil track density.

All of the fission-track apparent ages from the northern Plomosa Mountains, except for the zircon age of sample DF90-221, are younger than the initiation of extension in this area (~24 Ma: e.g., Spencer and Reynolds, 1991) and appear to record cooling related to extensional faulting and denudation. For each sample where they were both obtained, zircon and apatite fission-track ages are concordant for the footwall samples. For two of the four samples with both apatite and zircon ages the zircon apparent age exceeds the apatite age and for the other two samples the apatite apparent age exceeds the zircon age. The reversal in fission-track age for the later two samples is probably due to scatter in the data, because the ages overlap within 1 σ error.

In summary, the zircon and apatite apparent ages from the same samples are concordant and indicate very rapid cooling of each sample location along the exposed footwall through the annealing temperature intervals for zircon (<200°C) and apatite (<120°C). The zircon and apatite fission-track ages from the southern part of the transect, in the area of samples DF90-226 and -227, are also concordant with the minimum $^{40}Ar/^{39}Ar$ ages of two potassium feldspars (Knapp and Heizler, 1990). Knapp and Heizler (1990) calculated closure temperatures of 210°-290°C for these feldspars dates. The exact cooling rates for the individual samples cannot be calculated because of the rather large errors on the fission-track ages for each mineral, but they were probably ~25 - 100°C/m.y. Rapid cooling is also indicated by the long mean track lengths (~14 μm) of the samples (Gleadow and others, 1986).

We interpret the decrease in apparent fission-track age for the footwall samples shown in Figure 2 to be due to the progressive northward unroofing of crystallize rocks along the Plomosa detachment fault. Similar age trends of thermochronologic data in the slip directions of detachment faults are well established in the metamorphic core complexes of the Whipple tilt domain (Foster and others, 1990; Richard and others, 1990; Bryant and others, 1991; Foster and others, in press). The older zircon fission-track age of sample DF90-221 supports the interpretation that this sample is from the hanging wall because it must have been at significantly cooler temperatures (<200°C) than the samples from the footwall before the mid-Tertiary.

Most extension in the area around the northern Plomosa Mountains appears to have ended by ~18-19 Ma (Spencer and Reynolds, 1991). All of the zircon fission-track ages are consistent with rapid cooling due to tectonic denudation ending at about this time. However, the two apatite fission-track ages of 14 and 15 Ma from the northern part of the range are younger than the time at which major faulting is thought to have ended. This suggests that the northern-most part of the Plomosa Mountains (both the footwall and hanging wall blocks) remained at about 2-3 km depth, perhaps buried beneath Tertiary strata, until after detachment faulting ended and until ~15 Ma.

One of the aims of this research was to further constrain the amount of tilting that the northern Plomosa Mountains underwent during extension and to estimate the syn-extensional geothermal gradient. The present data do not constrain either of these because all of the apparent ages from the footwall are younger than the time of initial movement on the Plomosa fault. We are presently undertaking an $^{40}Ar/^{39}Ar$ study of potassium feldspars from these samples to obtain the needed information about the relative temperatures of each of the footwall samples before faulting.

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Table 1. Fission-track results - northern Plomosa Mountains, Arizona.

Sample number	Number of grains	Track Density ($x10^6 cm^{-2}$) Standard	Fossil	Induced	χ^2 (%)	Age* (Ma)	Uranium (ppm)	Mean Track Length (µm)	Standard Deviation (µm)
				apatite					
DF90-220	17	1.202 (2985)	0.067 (26)	1.051 (410)	96	**15 ± 3**	10.6	13.6 ± 0.5 (14)	1.8
DF90-221	10	1.307 (2985)	0.535 (107)	9.040 (1808)	7	**14 ± 1**	90.6		
DF90-222	20	1.313 (2985)	0.091 (46)	1.356 (683)	>99	**16 ± 2**	13.5		
DF90-223	19	1.317 (2985)	0.060 (53)	0.729 (644)	29	**19 ± 3**	7.2	13.9 ± 0.1 (2)	0.2
DF90-224	20	1.327 (2985)	0.181 (98)	2.378 (1294)	68	**18 ± 2**	23.5	14.0 ± 0.2 (52)	1.5
DF90-225	15	1.333 (2985)	0.150 (73)	1.567 (761)	49	**23 ± 3**	15.4	14.1 ± 0.2 (45)	1.4
DF90-226	18	1.347 (2985)	0.260 (135)	2.797 (1453)	46	**22 ± 2**	25.5	13.3 ± 0.5 (22)	2.3
DF90-227	20	1.353 (2985)	0.025 (27)	3.434 (373)	>99	**17 ± 3**	3.1		
					zircon				
DF90-220	9	0.827 (2392)	1.699 (432)	3.139 (798)	<1	**18 ± 2**	197.4		
DF90-221	6	0.813 (2392)	7.406 (385)	4.424 (230)	26	**55 ± 5**	283.0		
DF90-223	6	0.870 (2392)	2.142 (225)	4.493 (472)	44	**17 ± 2**	268.5		
DF90-225	6	0.912 (2392)	4.051 (613)	8.063 (1220)	<1	**20 ± 3**	459.7		
DF90-227	8	0.917 (2392)	3.457 (227)	5.680 (373)	87	**23 ± 2**	322.2		

Brackets show number of tracks counted. Standard and induced track densities measured on mica external detectors and fossil track densities on internal mineral surfaces. Apatite ages calculated using a Zeta of 353 for dosimeter glass SRM612 and zircon ages using a Zeta of 81 for glass U3 (Hurford and Green, 1983).

* Mean age, used where pooled data fail χ^2 test at 5%.

FIGURE CAPTIONS

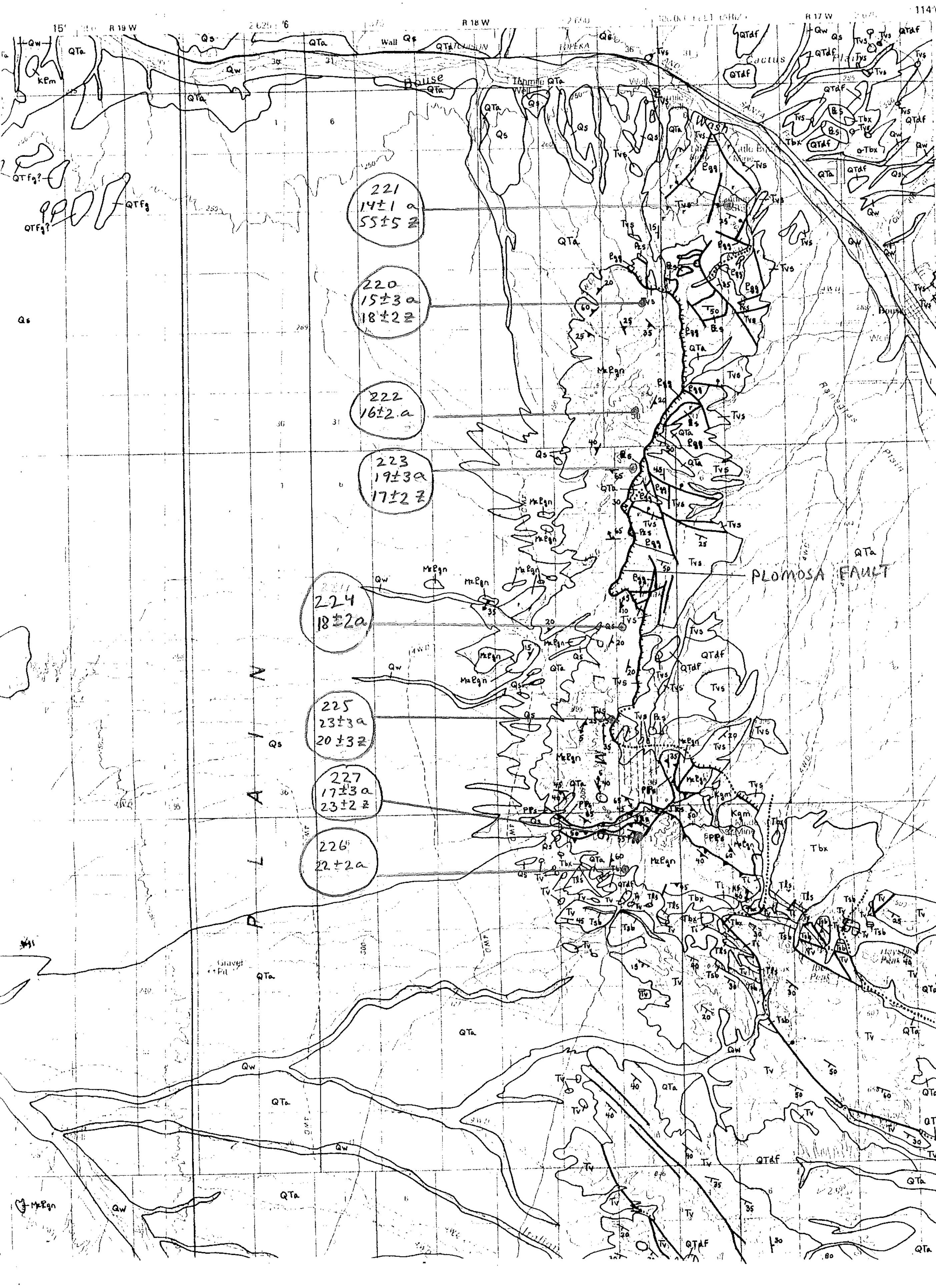
1. Geologic map of the northern Plomosa Mountains (Stone, 1990) with sample locations for fission track analyses.

2. Plot of the relationship between apatite and zircon fission-track age ($\pm 1\sigma$) and distance in the slip direction (N45°E) of the Plomosa fault for samples from the northern Plomosa Mountains. The solid line divides samples collected from the footwall to the Plomosa fault from samples collected from the hanging wall to the fault.

Stone, Paul, 1990, Preliminary geologic map of the Blythe 30' by 60' quadrangle, California and Arizona: U.S. Geological Survey Open-File Report 90-497, scale 1:100,000.

FIG. 1

DF-90 SAMPLE LOCATIONS AND FISSION-TRACK AGES



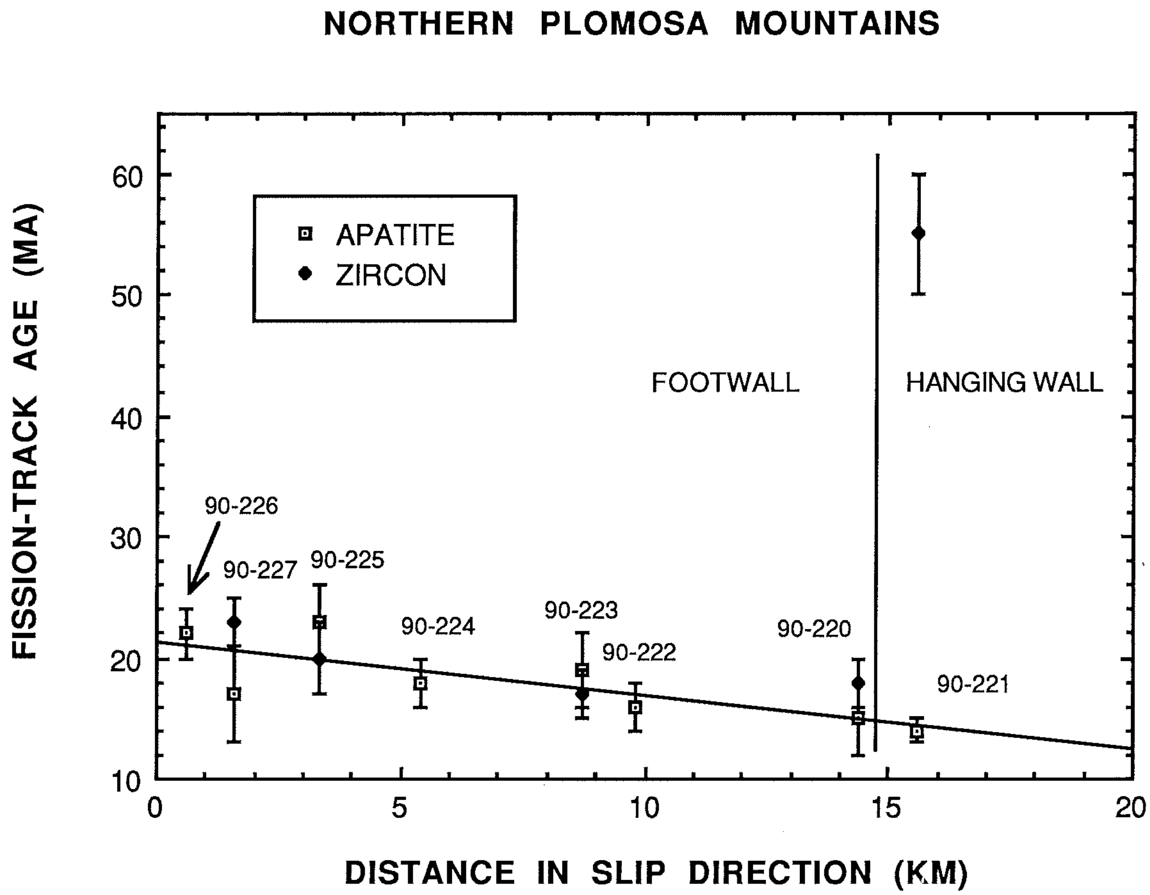

NORTHERN PLOMOSA MOUNTAINS
APATITE
ZIRCON
FOOTWALL
HANGING WALL
90-226
90-227
90-225
90-224
90-223
90-222
90-220
90-221
FISSION-TRACK AGE (MA)
DISTANCE IN SLIP DIRECTION (KM)
10
20
30
40
50
60
0
5
10
15
20

Figure 2