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Parra et al.,

Detecting earliest shortening and deformation advance in thrust-belt hinterlands: Example from the Colombian Andes

1. Fission Track analyses

Apatite preparation was done by Apatite to Zircon Inc. Apatite grains were concentrated following conventional heavy liquids and magnetic separation procedures. Apatite grains were then immersed in an epoxy resin and cured at 90°C for 1 h. After grinding and polishing to expose internal surfaces, the apatites in the first mount were etched in 5.5 HNO_3 for 20.0 s (±0.5 s) at 21°C (±1°C) to reveal spontaneous tracks. Analytical procedures followed the external detector method (Gleadow, 1981). Samples were irradiated at the Oregon State University research reactor. Following irradiation, induced tracks were etched with 40% hydrofluoric acid at 21°C for 45 min. Fission tracks were counted at the University of Potsdam using 1250 X magnification (dry objective) in a Leica DMRM microscope with drawing tube located above a digitizing tablet, and a Kinetec ™ computer-controlled stage driven by the FTStage program (Dumitru, 1993). Ages and errors were calculated using the zeta calibration method (Hurford and Green, 1983) with the software Trackkey (Dunkl, 2002), and are reported at the 1s level. A zeta calibration factor of 350.7 ± 6.0 for apatite (CN5 glass; M.Parra) was used for age calculations.

In samples with sufficient apatite yield, a second mount of grains was prepared. The grain mounts were then irradiated with approximately 10^7 tracks/cm^2 fission fragments from a 50 μCi (activity as of July, 1996) ^{252}Cf source in a vacuum chamber in order to enhance the number of confined tracks available for measurement (e.g., Donelick and Miller, 1991; Donelick et al., 2005). Irradiated grain mounts were then re-immersed in 5.5N HNO_3 for 20.0 seconds (± 0.5 seconds) at 21 °C (± 1°C) to reveal any horizontal, confined fission tracks, and the freshly-exposed confined tracks were then measured. Both track lengths and the angle to the *c*-axis were measured by M. Parra using unpolarized light. For each apatite grain from which fission-track age or length data were collected, an arithmetic mean value for the kinetic parameter Dpar (Donelick et al., 2005) was determined from 1 to 4 measurements.

Complete AFT results are presented in Table DR1.

2. Thermal Modeling

The thermal histories for the two Cretaceous sedimentary rocks presented in Figure 4B were obtained through inverse modeling of apatite fission-track ages and lengths, and vitrinite reflectance data, using HeFTy v 1.6.7 (Ketcham, 2005). We modeled kinetically homogeneous populations [i.e, the grains that, having similar Dpar, yield a concordant age ($P(\chi 2)>5\%$)] using c-axis projected track lengths (Ketcham et al., 2007a), and the apatite multicompositional kinetics model of Ketcham et al., 2007b). Maximum burial temperatures in the t-T paths were further constrained with available vitrinite reflectance measurements (Table DR2) according to the kinetic model of Burnham and Sweeney, 1989. Additional constraints (boxes delimiting the t-T space allowed for the thermal history) for thermal modeling were chosen so that t-T paths honor

the known geological history of the samples as follows: (1) a provenance constraint that allow residence at a wide range of temperatures before sediment accumulation; (2) a depositional constraint that enable permanence of the sample at surficial temperatures of 15-25°C during sediment accumulation; (3) a burial constraint allowing for a wide space for both, a potential early onset of cooling from temperatures hotter than that derived from the vitrinite reflectance data, and a broad range of subsequent cooling paths. We used two monotonic consistent half-segments between adjacent constraints using a gradual or intermediate randomizer style (Ketcham, 2005). A number of ~11000 to ~89000 models was ran until 20 to 50 good fits (GOF>0.5, see Ketcham, 2005) were obtained. Input and output data for thermal models are presented in Table DR3.

Figure Captions

Figure DR1: Composite refection seismic line for the northern Middle Magdalena Valley (MV) basin (see Fig. 1 for location). Interpretation emphasizes the available well control, a regional, Late Cretaceous-Paleogene unconformity, and structural relationships below the unconformity.

Figure DR2: Blow-up of reflection seismic Line 4 in the northern Middle Magdalena Valley (MMV) basin (see Fig. 1 for location). Interpretation emphasizes the available well control, a regional unconformity, and structural relationships below the unconformity.

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TABLE DR1. APATITE FISSION-TRACK DATA

ID #	Sample Number	Long (W)	Lat (N)	Elev. (m)	Unit	Strat position (km) *	Strat. Age (Ma)	# Gr	U (ppm)	Rho-S (NS) †	Rho-I (NI) †	Rho-D (ND) §	P(χ2) (%) #	Age (Ma) **	±1 σ error	Dpar (mm)	Cl (%wt)	±1 σ	#	Length (μm)	error (μm)	St dev (μm)	# length	Source ††
660-15	RS-SS30	73.414	7.107	194	Esmeraldas Fm.	3.00	40 ± 5	9	30	15.96 (244)	29.62 (453)	11.28 (1707)	0%	**65.8**	**30.1**	N.D.§§	0.13	0.18	9	11.18	0.53	1.67	10	1
660-14	RS-SS26	73.412	7.106	167	Esmeraldas Fm.	2.74	40 ± 5	5	38	4.708 (32)	35.46 (241)	10.59 (1707)	8%	**27.6**	**5.3**	N.D.	0.34	0.38	5	10.24	2.07	5.07	6	1
660-12	RS-SS21	73.407	7.104	244	Esmeraldas Fm.	2.43	40 ± 5	4	21	6.329 (47)	19.66 (146)	10.66 (1707)	2%	**73.5**	**20.2**	N.D.	0.53	0.68	4	9.74	0.74	2.85	15	1
660-08	RS-SS17	73.406	7.104	272	La Paz Fm.	2.15	51 ± 6	15	22	4.013 (125)	21.03 (655)	10.74 (1707)	0%	**40.3**	**7.7**	N.D.	0.59	0.58	15	11.62	0.32	1.07	11	1
660-07	RS-SS14	73.402	7.103	386	La Paz Fm.	2.00	51 ± 6	8	30	3.558 (45)	28.78 (364)	10.81 (1707)	97%	**26.2**	**4.2**	N.D.	0.59	0.58	8	8.94	1.36	2.71	4	1
660-06	RS-SS10	73.401	7.103	450	La Paz Fm.	1.81	51 ± 6	26	34	6.894 (318)	32.08 (1460)	10.89 (1707)	0%	**40.8**	**5.1**	N.D.	0.50	0.54	26	11.56	0.19	2.15	132	1
660-05	RS-SS08	73.395	7.100	315	La Paz Fm.	1.31	51 ± 6	4	12	1.30 (9)	11.12 (77)	10.96 (1707)	5%	**25.1**	**8.9**	N.D.	0.41	0.22	4	N.A.	N.A.	N.A.	0	1
660-04	RS-SS05	73.394	7.099	299	La Paz Fm.	1.20	51 ± 6	28	19	3.86 (317)	18.22 (1496)	11.04 (1707)	1%	**45.5**	**4.6**	N.D.	0.53	0.50	28	10.52	0.24	2.58	118	1
660-02	RS-SS02	73.392	7.100	341	Lisama Fm.	1.06	61 ± 5	20	15	1.483 (87)	15.07 (884)	11.11 (1707)	1%	**22.3**	**4.2**	N.D.	0.40	0.54	20	9.85	0.46	2.10	21	1
660-01	RS-SS01	73.384	7.086	340	Lisama Fm.	0.54	61 ± 5	25	17	3.080 (216)	16.46 (1156)	11.19 (1707)	1%	**36.0**	**5.3**	N.D.	0.20	0.34	25	10.25	0.39	2.80	51	1
1018-03	RS 011409-1	73.327	7.217	407	Lisama Fm.	0.25	61 ± 5	3	14	6.02 (27)	15.386 (69)	11.941 (8201)	20%	**81.4**	**18.6**	1.29	N.D.	0.12	3	N.A.	N.A.	N.A.	0	2
1018-04	BB 011309-	73.357	7.085	316	Umir Fm.	-0.52	74 ± 9	20	15	4.326 (62)	15.56 (223)	12.08 (8201)	66%	**58.6**	**8.5**	2.29	N.D.	0.539	20	12.4	0.22	1.51	49	2
660-37	Umir-SS	73.350	7.078	291	Umir Fm.	-0.84	74 ± 9	20	13	3.497 (169)	17.38 (840)	14.72 (2335)	44%	**56.1**	**4.9**	N.D.	1.22	0.59	20	12.73	0.40	1.91	23	1
1018-05	BB 011309-2	73.306	7.149	794	La Luna Fm.	-1.10	85 ± 5	14	59	6.284 (68)	38.441 (416)	12.218 (8201)	32%	**34.9**	**4.6**	1.657	N.D.	0.375	12	10.084	1.23	2.466	4	2
1018-06	BB 011309-4	73.289	7.164	983	Simiti Fm.	-2.30	106 ± 6	15	27	8.091 (198)	33.877 (829)	12,357 (8201)	23%	**51.5**	**4.2**	1.38	N.D.	0.18	14	12.11	0.26	1.65	39	2
660-36	Tablazo-1-SS	73.350	7.040	316	Tablazo Fm.	-2.42	118 ± 6	21	27	11.40 (305)	35.60 (952)	14.88 (2335)	0%	**65.5**	**17.1**	N.D.	0.09	0.13	21	11.14	0.28	1.38	24	1
1018-07	BB 011309-7	73.281	7.179	1148	Tablazo Fm.	-2.60	118 ± 6	21	27	5.331 (158)	26.486 (785)	12.495 (8201)	92%	**43.9**	**3.9**	1.477	N.D.	0.284	21	N.A.	N.A.	N.A.	0	2
1018-08	BB 011309-9	73.276	7.145	1150	Tambor Fm.	-3.60	138 ± 8	1	48	3.846 (3)	52.568 (41)	12.634 (8201)	N.A.##	**16.2**	**6.9**	1.24	N.D.	N.A.	1	N.A.	N.A.	N.A.	0	2
1018-09	BB 011309-	73.253	7.124	1115	Giron Gr.	-5.20	161 ± 15	5	29	8.411 (41)	36.105 (176)	12.773 (8201)	2%	**60.4**	**20.7**	1.68	N.D.	0.84	5	N.A.	N.A.	N.A.	0	2
660-34	Giron-SS	73.258	7.125	1125	Giron Gr.	-5.25	161 ± 15	2	19	1.673 (6)	25.65 (92)	15.12 (1733)	63%	**18.7**	**7.9**	N.D.	0.36	0.14	2	N.A.	N.A.	N.A.	0	1
1018-10	BB 011309-	73.192	7.104	1133	Giron Gr.	-7	161 ± 15	2	34	9.402 (33)	50.146 (176)	12.911 (8201)	35%	**42.3**	**8.1**	1.065	N.D.	0.473	2	N.A.	N.A.	N.A.	0	2

* Stratigraphic position of samples from the Eastern Cordillera with respect to a datum, choosen at the base of the Lisama Formation

† RhoS and Rho I are the spontaneous and induced tracks density measured, respectively (x 10^5 tracks/cm^2). NS and NI are the number of spontaneous and induced tracks counted for estimating RhoS and

§ RhoD is the induced track density measured in the external mica detector attached to CN2 dosimetry glass (x 10^5 tracks/cm^2). ND is the number of induced tracks counted in the mica for estimating RhoD.

\# (χ2) (%) is the chi-square probability (Galbraith, 1981; Green, 1981). Values greater than 5% are considered to pass this test and represent a single population of ages

** Pooled (central) age reported for ages that pass (fail) the χ2 test

†† 1. Gomez (2001) ; 2. This study

§§ N.D.: No data

N.A.: Not applicable

TABLE DR2. VITRINITE REFLECTANCE DATA

Sample Number	Long (W)	Lat (N)	Unit	Strat position (km)*	Ro (%)	S.D (%)	Source*
RS-G26	73.348	7.234	Esmeraldas Fm.	2.50	0.53	0.03	Gomez, 2001
RS-G13	73.340	7.232	La Paz Fm.	1.75	0.55	0.05	Gomez, 2001
RS-PL1	73.330	7.220	Lisama Fm.	0.60	0.48	0.05	Gomez, 20031
N.D.†	73.368	7.094	Umir Fm.	-0.30	0.53	0.03	Rangel et al., 2002
CE-Umir	73.377	7.684	Umir Fm.	-0.80	0.61	0.05	Ecopetrol-ICP, 2003
CE-Luna	73.377	7.149	La Luna Fm.	-1.20	0.77	0.04	Ecopetrol-ICP, 2003
CE-Simiti	73.377	7.154	Simiti Fm.	-2.30	0.82	0.06	Ecopetrol-ICP, 2003

* Stratigraphic position of samples from the Nuevo Mundo Sincline with respect to a datum,

† N.D.: No data

TABLE DR3. RESULTS OF APATITE FISSION-TRACK MODELING

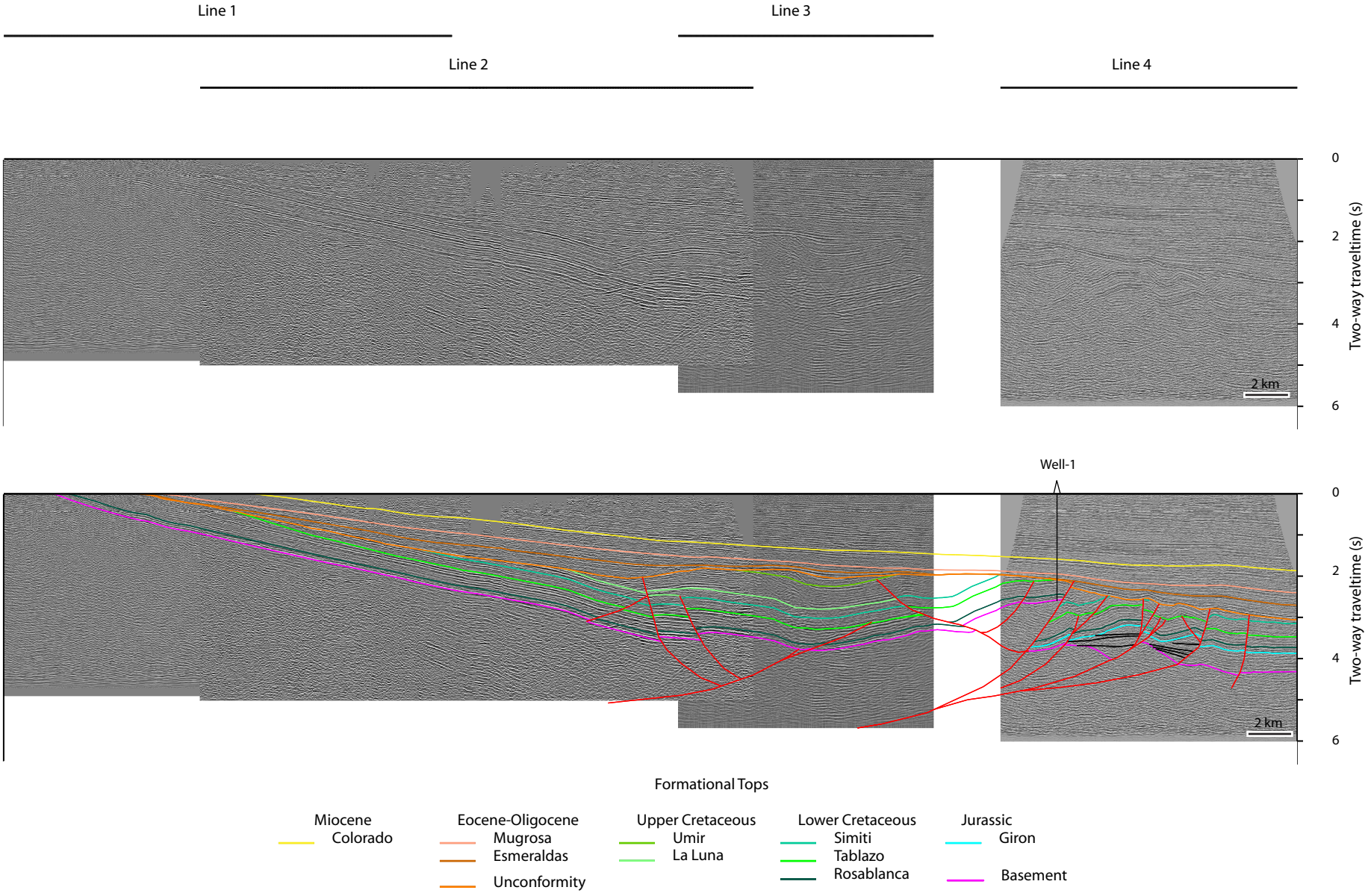
Sample	Kinetic Age							Length				Vitrinite reflectance			
	Cl (wt%)	Dpar (μm)	N	Model (Ma)	Measured (Ma)	GOF *	Old (Ma) †	N	Model (μm)	Measured (μm)	GOF *	Model (%)	Measured (%)	GOF *	Ro Model §
1018-04	N.D#	2.77	20	57.8	58.6 ± 8.5	0.92	104.0	50	13.60 ± 1.43	13.98 ± 0.94	0.79	0.70	0.70 ± 0.05	0.95	Easy Ro%
1018-06	N.D	1.16	15	50.4	51.6 ± 4.2	0.78	57.9	39	14.11 ± 1.01	13.71 ± 1.14	0.48	0.79	0.70 ± 0.05	0.70	Easy Ro%

* GOF is the goodness of fit between measured and modeled data (Ketcham, 2005); A good fit has GOF>0.5; an acceptable fit has GOF>0.05

† Oldest track modeled

§ Vitrinite reflectance model employed for calibration between Ro value and temperature (see Ketcham, 2005)

N.D.: No data



FigA1_Parra.ai

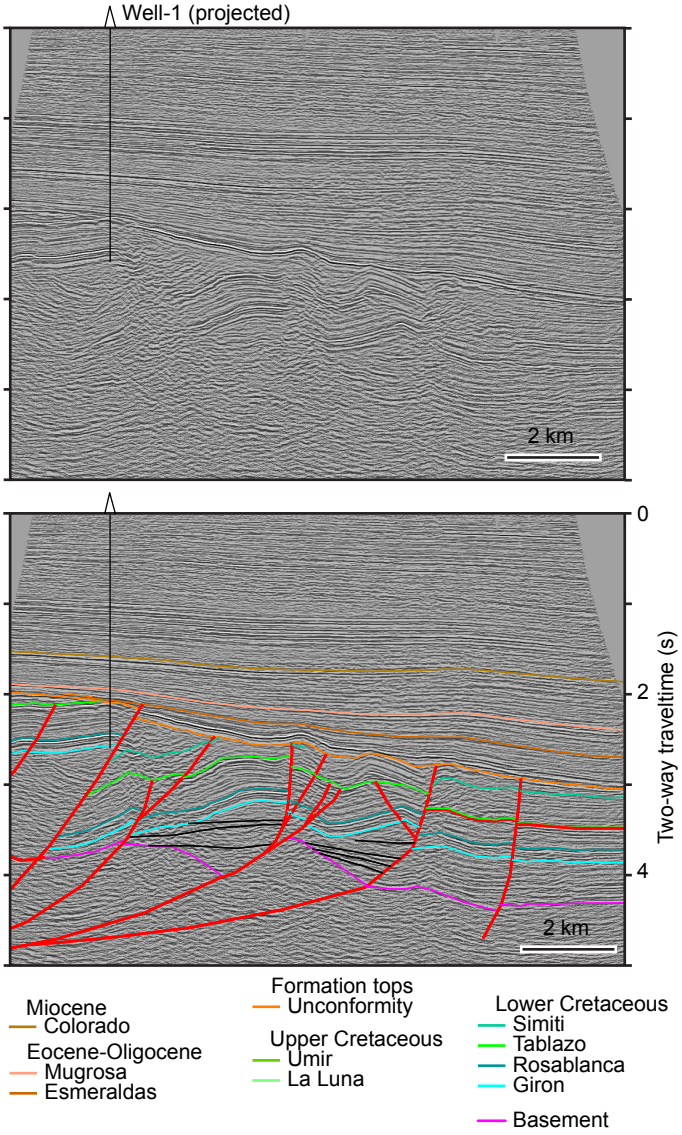


Fig 2_Parra.ai