Modeling Flat Subduction Initiation and Accretion of the Pelona Schist

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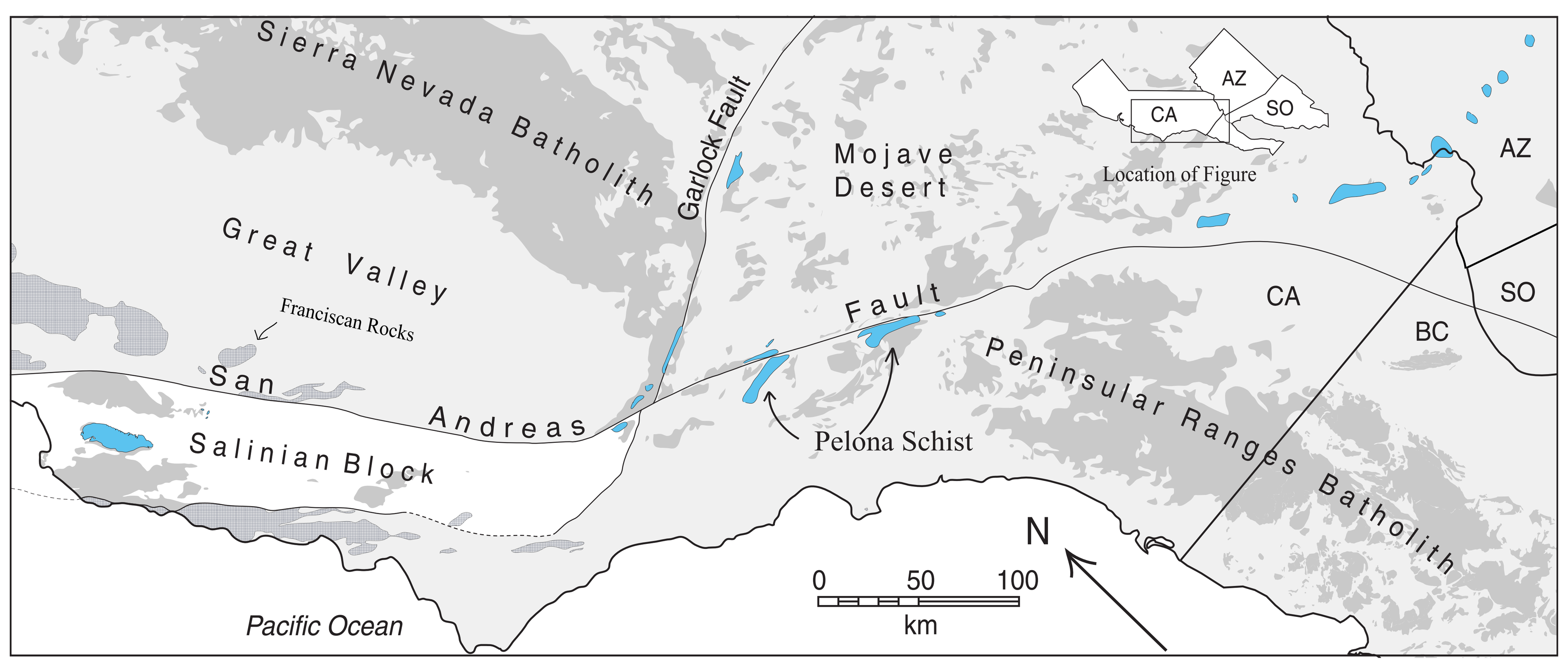
Summary

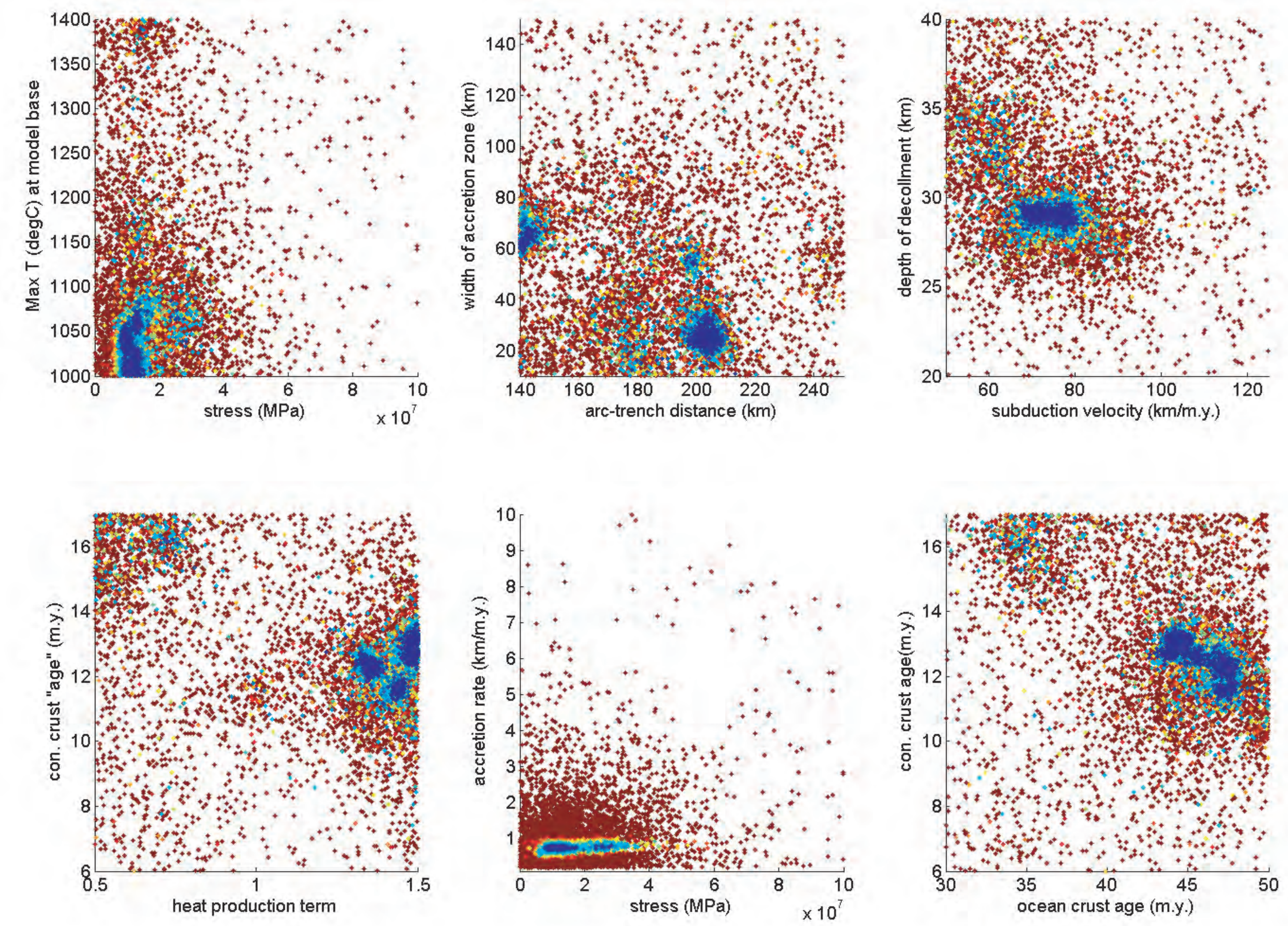
The Pelona and related schists of Southern California represent continental detritus deposited, subducted to depths of ~30 km, and accreted during a major Late Cretaceous-Early Tertiary collisional event. Emplacement of the schists coincided with the termination of magmatism along a ~500 km segment of the California continental arc, the disappearance and probable subduction of the forearc and western portions of the arc, and the loss of the mafic lower crust and root of eastern portions of the arc. Conceptual models of schist emplacement differ in detail, but generally involve a dramatic flattening of subduction. In order to better understand the stresses, accretion rates, and emplacement histories of the schists, we constructed a two-dimensional, finite element, kinematic-thermal model of flat subduction initiation using the program Pecube (Braun, 2003). Solutions were found using the neighborhood algorithm inversion scheme of Sambridge (1999).

The inversion uses 13,500 models with 10 parameters. A misfit function is defined using constraints available from the literature on upper plate cooling rates in the San Gabriel Mtns. (~15°/m.y.). Numerous models are able to satisfy the thermochronologic data using reasonable parameter values. Shear stresses in acceptable models fall between .5 MPa and 35 MPa. Acceptable accretion rates were between .5 and 1 mm/yr. Future models will also incorporate constraints on the inverted metamorphic gradient in the Sierra Pelona.

The inversion suggests that the thickest exposures of schist were built over 4-8 m.y. as material was scraped off 300-600 km of lower plate. In two less widely accepted alternative tectonic models, the schists represent either transpressional basin or forearc Great Valley deposits. Both alternative basin types are too narrow (<100 km) to produce the observed schist thicknesses.



Map of Southern CA showing Mesozoic plutonic rocks in dark gray. Pelona and related schists are shown in light blue.



Inversion of thermal model. Each dot represents a forward model in the parameter space (blue dots= good fit, maroon dots= poor fit)

Best fit model parameters
and misfit scheme

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BEST MODEL PARAMETERS:

stress=9682448.        !shear stress (Pa), standard 10.e6, range: 0-100
arctrench=201.258      !distance (km) from trench to where tracked particels
                        accrete, range: 140-250 km
ddepth=29.121          !depth of decollment flat (km), range: 20-40 km
Peclet=76.168          !slip rate on decollment (km/m.y.)
tmax=1040.875          !temp at model base (deg C), range: 1000-1400
acr=.752               !accretion rate (km/m.y.), range: .1-10
az=23.992              !width (km, in x direction) of accretion zone
ocrustage=43.935       !T&S age (m.y.) of oceanic crust, vary 4 to 60
concrustage=13.078     !T&S 'age' (m.y.) of 'continental' crust, range:
hpt=1.483              !heat production tuning parameter, vary .5 - 1.5 to
                        vary % of Brady heat prod.

MISFIT SCHEME:

hs=150./(Kage(11)-Mage(11))   !SK cooling rate 300-150 @ +10 km
cr=200./(Mage(12)-Hage(12))   !SK cooling rate 525-300 @ +3.5 km
ig=Mage(8)-Mage(10)           !SK cooling time lag (~300deg) from +7 km to +1km
hsw=2.                        !SK weighting factor for hs, roughly the error
                               bar on data
crw=2.                        !SK weighting factor for cr
igw=1.                        !SK weighting factor for ig
hsfit=(hs-15.)/hsw
crfit=(cr-14.5)/crw
igfit=(ig-6.9)/igw
score=(hsfit**2.+crfit**2.+igfit**2.)**(1./2.)

RESULTS OF BEST MODEL:

cooling rate 300-150 @10 =      14.9   (hs-15.)/  2.0 =  -0.05
cooling rate 500-300 @3.5=      14.8   (cr-14.5)/  2.0 =    0.14
cooling lag              =       6.7   (ig-6.9)/  1.0 =  -0.20
peak temperature @ 200m  =      532.0   (pk-587.)/ 50.0 =   -1.10
inv gradient             =      126.7  (ig-240.)/ 40.0 =  -2.83
score=                        3.0
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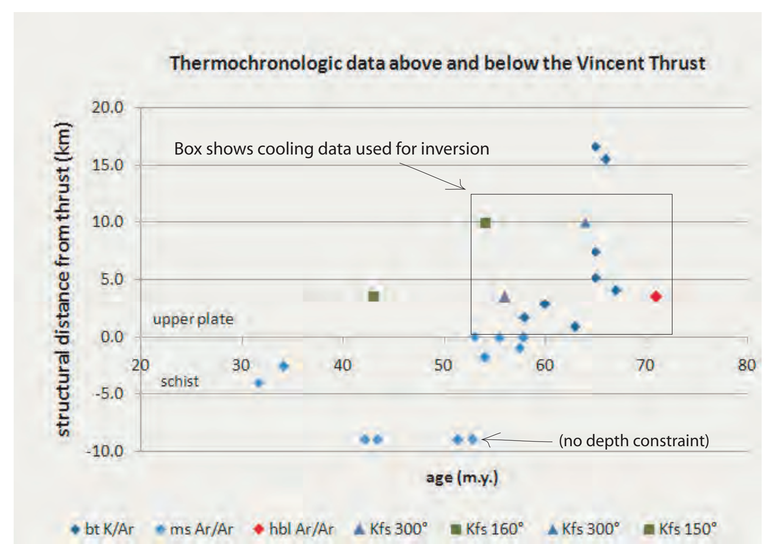
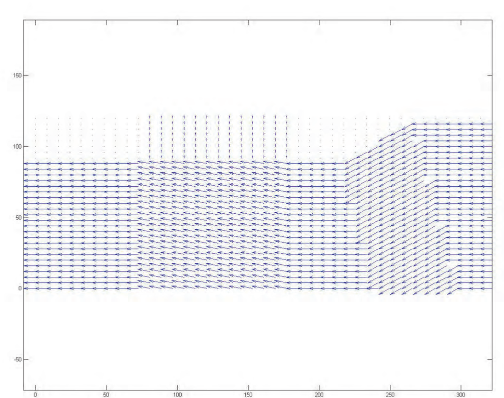
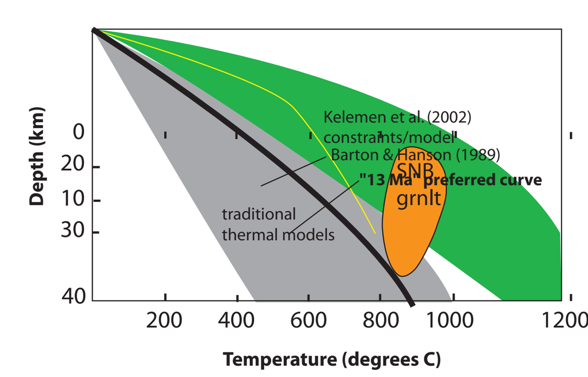


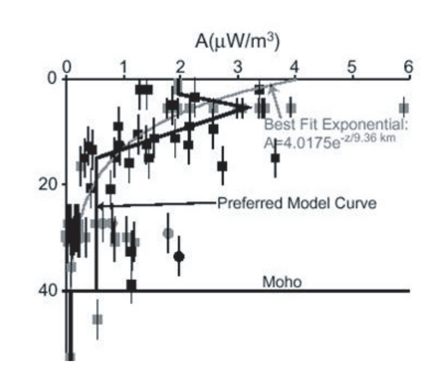
Thermochronologic data from the San Gabriels Mtns. Box indicates data used to constrain the model



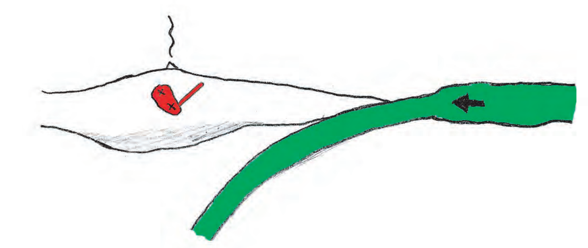
model kinematics



Arc thermal gradient of best fit model



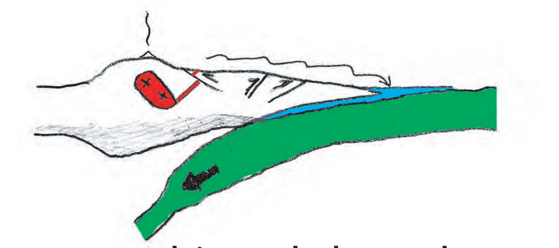
heat production step function used



t=0 m.y.

Overthickened oceanic crust approaches, zircons crystalize

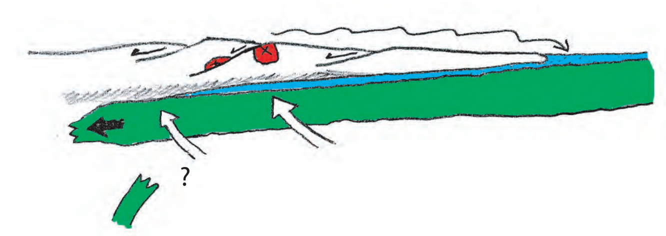
t=1 m.y.



t=2 m.y.

Uppermost schist subducted, young zircons transported to schist

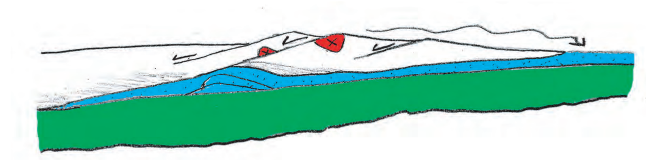
t=3 m.y.



t=4 m.y.

Accretion & extension begin, upper plate cooling through 500 C, uppermost schist at peak T metamorphosed

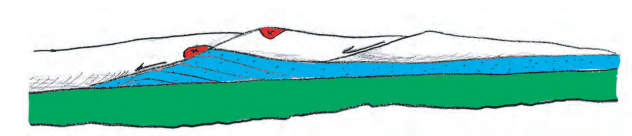
t=5 m.y.



t=6 m.y.

Exposed schist accreted, continued extension w/TTNE shear sense

t=10 m.y.

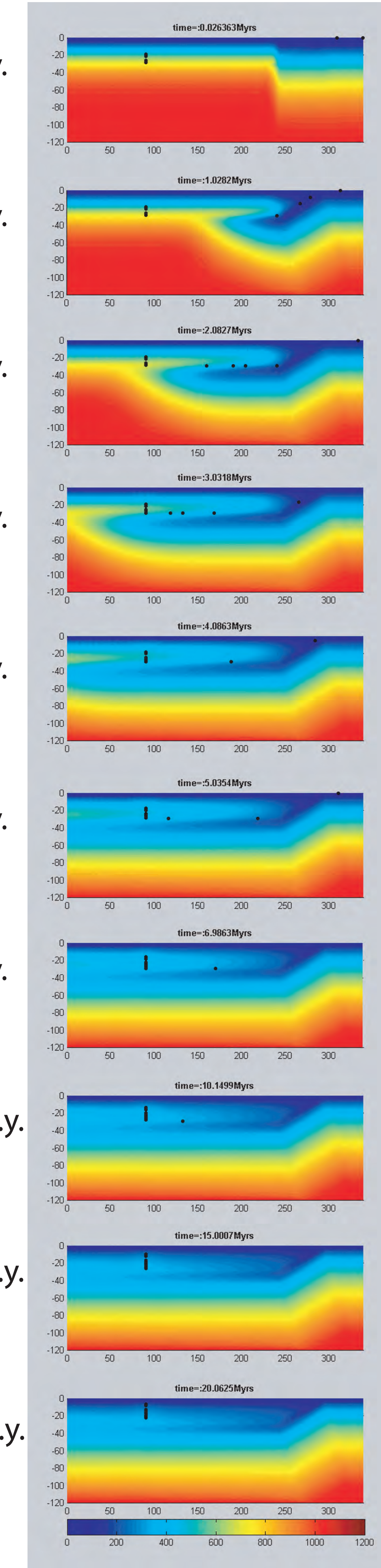


Schist juxtaposed w/TTNE shear sense against current upper plate

t=15 m.y.

Schist cools through low temperature limit of Kfs Ar/Ar technique (multiple diffusion domain model of Lovera et al, 1989)

t=20 m.y.



Model results and cartoons depicting a tentative sequence of events