

Fig. 10. Fission-track constraints on the time of commencement of cooling for all AFTA samples in this study for which there is clear evidence for paleo-heating (time constraints are also summarized in Table 3 for each sample). Results show strong and consistent evidence for two widespread events in which cooling commenced between 100 and 90 Ma, and sometime in the last 20 Ma; some solutions fall off the main trend, permitting to presume an intermediate event between 65 and 50 Ma. Note this conclusion is based on the simple assumption that the events occurred synchronously across the study area, as illustrated by the interpreted overlap in the timing of events. Important, as illustrated above, considerably more intra-plateau complexity would be allowed in the Borborema region if the assumption of synchronicity was not imposed.

- ii. Other less dominating, intermediate event of Paleogene–Eocene age is recorded in the region (samples RD57-17, -21, -29, -31), as well as the possibility of an older event is suggested by the sample RD57-23.
- iii. It is not clear whether the main events can be represented as a single long-term cycle of continuous cooling, or if they represent discrete episodes of heating/cooling, in which basement was uplifted to or near the surface during the interval between the two events. If the recognized events are caused by paleo-burial, followed by erosion, the results demand kilometer-scale uplift and denudation of the crystalline basement, in the order of 1000–3000 m, since the mid Cretaceous breakup. Obviously, the estimate of erosion relies heavily on the assumed paleogeothermal gradient (and hence is associated with significant uncertainty, as different blocks may have been submitted to distinct thermal evolutions).

6. Significance of the fission-track results

Over the past few years there have been a number of fission-track studies from eastern Brazil (Gallagher et al., 1994; Karner et al., 1994; Hegarty et al., 1996; Harman et al., 1998; Hackspacher et al., 2004), none of which can be easily linked to topography generation and a causative tectonic event.

For example, Harman et al. (1998) in their study of the Guaporé and São Francisco cratons show fission-track ages that range from 309–137 Ma to 260–76 Ma, respectively. They suggest that their fission-track results demonstrate two main pulses of denudational cooling: (1) the first beginning at ~130 Ma, and (2) a younger episode of denudational cooling that began in the Late Cretaceous (~80–60 Ma). While the authors attempt to relate the first event with the initial stages of breakup, our results indicate that fission-track age resetting is occurring uniformly over a vast geographic region, 200–400 km away from the sites of rifting. Harman et al. (1998) have invoked shear zone reactivation, synchronous with the Santonian events of central Africa, as a possible mechanism controlling their 80–60 Ma event (Late Cretaceous). It is extremely unlikely that localized shear zone reactivation can generate broadly distributed and relatively high (100s of meters) topographic relief

across northeastern Brazil on a different plate than the observed Santonian inversion of central Africa (Guiraud and Bosworth, 1997).

The studies of both Gallagher et al. (1994) and Karner et al. (1994) show fission-track ages increasing with elevation towards the continental interior. This type of age profile is considered a “classic” response of rift flank denudation driven by slope retreat processes in which younger fission-track ages are at the base of the eroding escarpment and the older ages, reflecting minimal erosion/cooling, are towards the crest of the escarpment. The fission-track data in this study do not show this trend. In the Borborema Province, our derived thermal history solutions are somewhat similar across the entire study area, irrespective of rock type, stratigraphic age and elevation. We believe this response is best accounted for by regional denudation, but a component of higher heat flow cannot be ruled out, as various paleothermal events derived from fission-track analysis on the conjugate African margin (Bray et al., 2002) were in part controlled by elevated heat flow during the mid Cretaceous.

An active rift model, which in effect is a combination of plume dynamics with lithosphere extension, has long been hypothesized to drive the onset of rifting in northeastern Brazil (O'Connor and Duncan, 1990; Wilson, 1992; Lima Neto, 1998a; Thomaz Filho et al., 2000). Intracontinental rifting occurred in northeastern Brazil (e.g. the Rio do Peixe, Araripe and Iguatu Basins) between 140 and 118 Ma, and the amount of extension responsible for these interior basins was localized and minor ($\beta = 1.1$ –1.2; e.g. Magnavita et al., 1994). The minor extension led a number of authors to argue against the role of mantle plumes in triggering Early Cretaceous extension (e.g., Matos, 2000, 2001; Fairhead and Wilson, 2005). However, the broad zone of diffuse 145–125 Ma tholeiitic volcanism onshore (and younger volcanism offshore) northeastern Brazil, together with the restricted Late Albian volcanism in the Pernambuco–Paraíba Basin, requires a significant thermal anomaly within and large partial melting of the asthenosphere or mantle lithosphere.

Recently, Kuszniir and Karner (2007) proposed that continental lithosphere thinning leading to breakup is controlled by an upwelling, divergent flow field that depending on the ascent velocity versus the divergent velocity, preferentially thins the lower continental crust and lithospheric mantle during extension. The