Ridge-crossing seamount chains; a non-thermal approach

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In this paper we examine whether it is viable to form an age-progressive ridge crossing seamount chain using a non-plume mechanism. Non-thermal melt sources considered include fertile mantle blobs and sub-solidus mantle while lithospheric stresses generated at the ridge and at ridge-transform intersections are tapped to bring the mantle to the surface. Finite element models, analog models, and an analysis of the Tristan de Cunha chain all show that ridge-crossing seamount chains may be created using these mechanisms. Essentially, as a ridge migrates or reorganizes excess magmatism may appear to switch sides of the ridge as areas of extensional stress at the ridge-transform intersection migrate with the ridge.

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INTRODUCTION

Hypotheses for ridge-crossing seamount chains have focused on the interaction of mantle plumes with migrating ridge segments (DePaolo & Manga, 2003; Sleep 2002b). These hypotheses call for a stationary plume of hot mantle material that rises to the base of the lithosphere and creates a chain of age-progressive seamounts in the middle of the plate. As a migrating ridge approaches the plume, buoyant mantle material rises along the base of the lithosphere like a helium balloon along a cathedral ceiling to the ridge and age progressive chains of seamounts are created on both sides of the ridge from a single hotspot source. Eventually the ridge moves away from the plume and seamount production switches across the ridge to the other plate, ceases to generate seamounts on the ridge, and continues to generate seamounts on the new plate only (e.g., DePaolo & Manga, 2003; Sleep 2002b; Ribe et al., 1996; Kincaid et al., 1996; Small, 1995). This scenario results in the formation of an asymmetrical V-shaped array of seamounts such as the Tristan de Cunha chain in the South Atlantic (Figure 1).

Because current non-thermal models of seamount formation are unable to explain this geometry, (*e.g.* propagating cracks are presumed to be unable to cross ridges, and asthenospheric heterogeneities are presumed to be moving rapidly), ridge-crossing seamount chains have been cited as evidence for plumes of material that remain relatively stationary in comparison to the plates. However, if the mantle is lithologically heterogeneous and contains areas with different melting points on a scale from km to 100's of km and/or if ridge-transform intersections are involved, then non-thermal ridge-crossing seamount chains are not only viable, but also likely. In this paper we propose a mechanism for the development of ridge-crossing seamount chains that does not invoke deep mantle plumes yet still accounts for the four primary elements necessary for a viable hypothesis for the origin of seamount chains ranging in size from 2 or 3 seamounts to seamount chains spanning a 100 Ma. The primary elements included in this mechanism are; a source of melt, a means of bringing melt to the surface, an asymmetrical ridge-crossing seamount chain, and an explanation for the age progressive nature of the chain. Vogt and Jung (2005) proposed a similar mechanism using fertile mantle or anomalous mantle patches and migrating ridges, but did not account for the assymetrical nature of some of the chains. We address that issue here using seamount emplacement off ridge ahead of ridge-transform intersections.

MELT SOURCE

We focus on two alternative sources for the melt: 1) the mantle has fertile or low melting point regions, or 2) the mantle is in a nascent melting condition.

In the first case, the mantle is heterogeneous and contains fertile (e.g. compositionally different) streaks or blobs, some of which are large and produce major outpourings of magma when tapped, (*i.e.* when the stress condition in the overlying plate permits dikes and volcanoes to form). Fertile mantle streaks and blobs require lower temperatures or lower ascent rates to produce melt volumes similar to those modeled for infertile, deep mantle sources. In the second case, the mantle may be relatively homogeneous and is at, or near, its melting point. Under these conditions melt is created any time pressure drops or when the lithosphere extends and causes passive upwelling to occur. In both cases the stress conditions of the lithosphere will determine the form of the melt intrusion, ponds, sills, or dikes and volcanoes. Elements of these scenarios have been discussed previously by various authors (e.g. Favela and Anderson, 1999; Meibom & Anderson, 2003; Sleep, 2002b; Natland and Dick, 2001; Niu et al., 2001; Yaxley, 2000; McNutt & Bonneville, 1999; Anderson, 1998; and Sleep, 1997). Variants of these scenarios can be imagined. The asthenosphere is not expected to be precisely isothermal and small variations in temperature for a mantle near its solidus can produce large variations in melt content to be tapped by localized stresses and cracks. Because ridges themselves are moving, stresses and cracks associated with the ridges may tap mantle melt in a v-shaped pattern that appears to cross the ridge without invoking a deep mantle source.

MELT TRANSPORT

Melt is transported through the oceanic lithosphere to the surface to form seamounts in the form of dikes (e.g. Gudmundsson, 1990). Dikes require a horizontal least-compressive stress regime plus a source of melt. The overall state of stress in oceanic lithosphere is usually compressional, except near ridges; it is necessary for a change in the local stress field to occur for dike intrusion to commence (e.g. Zoback, 1992; Wiens and Stein, 1984; Richardson and Solomon, 1979). Otherwise, we have ponding, underplating and sill intrusion. A change in the stress field of an oceanic plate from compressional to tensional may be due to: localized upwelling of low-density material beneath the plate (Tentler, 2003; Sleep 2002a,b; Sleep, 1997); large-scale tectonic forces such as changes in subduction and plate reorganizations; plate flexure (Hieronymus and Bercovici, 2000); and regional stress patterns associated with ridges, transforms, microplates, and seamounts (e.g. Neves et al., 2004; Craddock et al., 2004; Shah and Buck, 2003; Bergman and Solomon, 1992). Thermal contraction of a cooling plate can explain some magmatism (Sandwell and Fialko, 2005). To account for a series of injection events that result in a chain of seamounts, these changes in the stress regime must be ongoing or self-sustaining for the lifetime of the chain, usually less than 15 Myr..

Previous hypotheses for seamount chain emplacement invoke a rising hot, buoyant deep mantle plume, to thin, weaken, and uplift the lithosphere. The buoyancy of the ponded magma creates a localized horizontal tensional stress field that overcomes the normal compressive state of oceanic lithosphere (Sleep, 2002b; Sleep, 1997). The ongoing supply of hot material from the plume tail sustains the buoyancy and maintains the tensional stress field. The episodic nature of the emplacement of the seamount chain is a result of the influence of the extruded and underplated material on the stress state combined with possible flux variations in the plume tail (i.e. Courtillot et al., 2003; Campbell, 2001, Richards et al., 1989). The melt source is the hot buoyant plume.

Other models propose that age progressive seamount chains may be the result of tensional stresses, tectonic cracking of the oceanic plate, or horizontal dike propagation extending pre-existing features (e.g., Favela and Anderson, 1999; Natland and Winterer, 2005; Fairhead and Wilson, 2005; Hieronymus and Bercovici, 2000). The development of a chain results from the propagation of the crack or dike in response to the stress field across the plate. Melt is either already available from underplated magma, from fertile blobs, and/or is created through decompression melting of the mantle in response to the extension of the crust. In the fertile blob model, melting creates buoyancy and the melting is sustained by adiabatic decompression as the material rises (Raddick et al., 2002). In these models it is the relative motion between the elements that is important, not the absolute motion as in the fixed plume model.

Horizontal tensional stress in a plate can also be created, at and ahead of, ridge-transform intersections when slip along the transform fault is impeded (Beutel, 2005; van

Wijk and Blackman, 2005; West et al., 1999; Phipps Morgan and Parmentier, 1984;; Fujita and Sleep, 1978; Lachenbruch and Thompson, 1972*)*. Large magnitude tensional stress field may cause decompression melting of fertile mantle regions of and mantle in a nascent melt condition. The resulting melt is then either transported to the surface through the cracks formed by the tensional stress, or it is ponded and increases the horizontal tensional stress until dikes develop and seamount formation occurs (Beutel, 2005). The applicability of this model for creating lithospheric extension is suggested by the observation that many seamount chains intersect, or originate, near RTIs (*e.g* Klingelhöfer et al., 2001; Johnson et al., 2000; Hekinian et al., 1999; Graham et al., 1999).

Large areas of extension develop in the lithosphere when transform slip is impeded (Figure 2) (Beutel, 2005). If the mantle is already partially molten, or if magma is ponded beneath the plate, then the condition for dike development is simply that the least compressive axis is horizontal. If the mantle is entirely subsolidus, then decompression is required to generate melt. Decompression and melt generation is expected to occur in response to lithospheric extension, such as occurs in the neighborhood of RTIs. Development of seamount chains rather than linear ridges is postulated to be a result of episodic strengthening and weakening of the transform fault due to changes in the local stress state, which occurs partially as a result of the injection of magma into the crust (Sleep, 2002b). Sustainability results from the ongoing presence of mantle at, or near, its solidus or the presence of a fertile mantle blob near the ever changing stress fields at RTIs.). Large amounts of melt probably require a fertile blob that is already above its melting point or pre-eruptive ponding.

MODELS

Based on our understanding of non-thermal melt sources and the transport of melt to the surface we have developed two models by which non-plume ridge-crossing seamount chains may be generated. These models are based on the following assumptions: due to welding or tectonic forces most transforms experience periods of decreased slip; when transform slip is impeded, extension is concentrated at, and ahead, of the RTI (Figure 2); if the mantle is fertile or near its solidus, extension at an RTI will result in the formation of a seamount; and ridges migrate and reorganize. We also examine this mechanism for the Tristan de Cunha seamount chain in the South Atlantic.

Model 1 – Ridge Reorganization (Figure 2):

Model 1 is illustrated in Figure 2. We examine the potential for a ridge-crossing geometry for seamount chains formed during a ridge reorganization over a near-solidus mantle. Because the mantle is near solidus it is assumed that concentrated horizontal tensional stress in the lithosphere will result in decompression melting, dike formation, and seamount emplacement. Finite-element models of an evolving ridge were constructed to determine the location of these tensional stresses and the resultant seamount pattern that would emerge during a ridge reorganization. More than 12 initial time frames were constructed, and the 6 most relevant are shown in a forward model of a reorganizing ridge. Figure 2 presents the finite-element model results as maximum stress type by color (red is tensional and blue is compressional), maximum and minimum stress vectors, and conceptual models of seamount emplacement and oceanic crustal ages and therefore motion are shown adjacent to the stress maps. The exact model parameters are given in the appendix. Stresses applied to the model consist chiefly of ridge-perpendicular gravity forces applied to the whole of the plate, thus plate motion is initially perpendicular to the ridge and becomes more oblique to the overall ridge over time.

O my.: Three north-south-trending ridge segments are connected by weak transforms. The oceanic plate is under relatively little east-west stress.

10 my: A change in plate motion direction results in NE-SW ridge-push forces and the strengthening of both transform faults. Large areas of tensional stress are concentrated ahead of and at the RTIs. Seamounts are emplaced in older crust ahead of the RTIs.

15 my: In response to changing plate motions a new NW-SE-oriented ridge propagates between the southern two ridge segments, eradicating the transform. The northern transform is modeled as weak. Extension is concentrated where the new NW-SE trending ridge intersects the middle NS-trending ridge segment. Seamounts are emplaced on the western plate only.

25 my: Re-strengthening of the northern transform results in tensional stresses at and ahead of the RTIs there. New seamounts are emplaced.

35 my: A new NW-SE-trending ridge segment propagates over the northern transform. Large tensional stresses are concentrated where the NS ridge segments

intersect the NW-SE trending segments, more seamounts are emplaced on the western plate.

45 my: A new, weak transform forms between the NW-SE trending ridge segments. Extension is still concentrated at the intersection of the NS- and NW-SE-trending ridge segments. Seamounts are emplaced on the western plate at the intersection.

Seamount Pattern:

The resulting seamount pattern is a pair of chains that increase in age away from the ridge, and appear to change from emplacement on both sides of the ridge to emplacement only on the west side. This results in the same seamount pattern that has been attributed to a ridge overrunning a hotspot (Sleep, 2002b). Recall that we only have information about the relative positions of ridges and fertile mantle blobs. The only difference between the generation of seamounts due to ridge-reorganization over a sub-solidus mantle and those generated by a plume is that a plume "burns" through the overlying lithosphere and thereby can emplace seamounts at will, while this model shows that the same results can be achieved by stress in the lithosphere releasing sub-solidus mantle from below to form the seamounts. However, if a plume did exist under the modeled ridge melt would likely still be guided by the stress fields modeled, making differentiating a plume source from an upper mantle source even more difficult.

While no one specific seamount chain is modeled in Figure 2, the ridge reorganization that is modeled is similar to ongoing and past ridge reorganizations in the Pacific. The high density of midplate seamounts in the Pacific compared with the Atlantic suggests that the mantle beneath the plates in the Pacific is closer to its solidus than mantle beneath the Atlantic plates or that the plates in the Atlantic are under a greater degree of horizontal compression.

Model 2 – A "Stationary" Fertile Blob: (Figure 3)

In this section we present both a conceptual model and a simple analysis of the Tristan de Cunha seamount chain. The conceptual model (Figure 3) takes the ridge geometry and motion proposed in Sleep (2002b) and applies the finite element modeled stresses to the ridge and moves the ridge over a fertile blob. A fertile blob that is stationary relative to the overlying lithosphere will have the same seamount pattern as a plume as long as a stress-field in the lithosphere exists to tap into it. In this model we show that the extensional stress fields ahead of ridge-transform intersections combined with the ridge itself may produce a pattern of ridge-crossing seamounts similar to a that of a plume.

In the second fertile blob model (Figure 4) we reconstructed the South Atlantic basin ridges for the last 80 Ma using the oceanic ages of Mueller et al. (1997), the ocean floor gravity signature of Smith and Sandwell (1997), and some seamount ages (O'Connor et al., 1999). A stationary fertile blob relative to a fixed reference frame (the border of the model) was also added. Once again, by assuming that seamounts can be formed at the ridge and in older oceanic crust ahead of ridge-transform intersections we were able to recreate the ridge-crossing chain. We acknowledge that at this time the active island of Tristan is not well understood, but submit that the location of Tristan is difficult for any model to place, its location near a strongly defined fracture zone suggests that lithospheric forces similar to those described at the ridge-transform intersections may be responsible.

Model 2a: Figure 3

In this conceptual model we apply the finite-element results of extension, at or ahead, of RTIs to a ridge migrating, in relative terms (both may be moving) over a fertile mantle region. This model assumes that seamounts only form when there is strong tensional stress above a fertile mantle region, and the tensional stress results from impeded slip on a transform fault. For ease of illustration, the fertile mantle blob in Model 2 was shown as stationary, but no actual stability relative to the Earth's core is implied, simply a point fixed in the mantle relative to a moving ridge.

Figure 3 is a schematic diagram that illustrates the modeling results separated into discrete time intervals. During the first four time periods (T1 - T4) a fertile mantle region is intersected by a series of RTIs as the ridge moves to the northwest. This results in a single chain of seamounts on the western plate, the spacing of which is determined by the production rate at, and the spacing of, the RTIs. The seamounts move to the northwest relative to one-another but to the west relative to the ridge. In time interval T5 the ridge overrides the fertile mantle region and chains of seamounts are created on both sides of the ridge. Finally, the ridge moves off the fertile mantle region and growth of the seamount chain on the western plate is terminated. In time interval T8 the fertile mantle region is intersected by an RTI on the eastern side of the ridge, and a new series of seamounts is initiated. The resultant seamount distribution gives the impression that the seamount chain has crossed the ridge.

Model 2b: Figure 4

The time series shown in Figure 4 is a reconstruction of the South Atlantic showing all areas of increased volcanism (seamounts and ridges), the ages of the ocean floor as determined by Mueller et al. (1997), and the ages of the main ridge crossing Tristan seamount chain (O'Connor et al., 1999). Also shown is the approximate location and geometry of the ridge as determined from the Mueller et al. (1997) data and an area of fertile mantle that may have contributed to the formation of seamounts both on the ridge and at and ahead of seamounts. Note that the change from seamount production on both sides of the ridge to just the eastern side of the ridge is associated with changes in ridge geometry versus and stationary point. All seamounts shown were either created at the ridge or could have been created ahead of a ridge-transform intersection in older crust.

80-60 Ma: It appears that a large area of fertile mantle could have created portions of the Walvis ridge at the ridge between 80 and 70 Ma and then between 70 and 60 Ma that portion of the oceanic crust slid past the series of east-stepping transforms. This would have resulted in repeated injection of magma .

60-40 Ma: During this time period the transforms become more distinct, no ridge propagation patterns are detected, but some degree of reorganization must have taken place if the Mueller et al. (1997) age lines are correct. The majority of seamount activity also switches from the South American plate to the African plate at this time. A reinjection of previously injected crust would account for some of this, as would the location of the fertile blob under and ahead of ridge-transform intersections on the African plate during ridge reorganizations and impeded transform slip.

40-20 Ma: A comparatively quiet time, the South American plate has few distinct seamounts, but rather boasts an overall increased heat and/or plate thickness as indicated by the gravity signature. The African plate has some distinct seamounts which appear to be have formed near the ridge-transform intersections. Ridge migration over the fertile blob would account for the seamounts at the ridge-transform intersection. The decrease in Africa's motion at this time (O'Connor et al., 1999) would have affected the stress-field at the ridge and may account for the difference in the style of magma injection.

20-10 Ma: Increased westward drift of the ridge results in the continued production of seamounts on the African plate at ridge-transform intersections.

10-0 Ma: Westward drift of the ridge puts the fertile mantle blob on the very fringes of the ridge and generates seamounts at the ridge-transform intersections on the long offset transforms. Tristan is created along an old transform.

Note: We only tracked one ridge-crossing seamount chain, however, given that the area was surrounded by inward dipping subduction zones only 230 Ma, it is likely that the area is rife with subduction derived fertile mantle blobs.

OTHER SEAMOUNT GEOMETRIES

Our first model, of lithospheric extension above a mantle near its solidus, accounts for the generation of numerous seamount chains some of which appear to cross the ridge, this seamount geometry is similar to that seen in the Pacific basin. The second model, with its single ridge-crossing seamount chain, has a more similar geometry to seamount chains in the Atlantic basin. The principles of RTI generated seamounts can also be applied to other observed geometries. The combination of on and off-ridge localized extension with mantle compositional anomalies may result in a great number of seamount geometries. For example; short seamount chains may result from small regions of mantle fertility and/or the migration of a ridge away from the fertile region whereas large areas of melt represented by aseismic ridges and large-igneous provinces may represent large regions of fertility or mantle in a nascent melting state. The more numerous seamounts and faster spreading rates in the South Pacific indicate that different mantle and lithosphere conditions in the region may affect seamount formation including strong thermal contraction of the lithosphere, a plate close to the tensile state, and/or numerous fertile patches or proximity to the nascent melting state.

LARGE IGNEOUS PROVINCES

Plume-based models for ridge-crossing-hotspots involve the separation of postulated plume heads (LIPs) from the ends of their tails (volcanic chains) by actively spreading ridges. Most volcanic chains, however, do not start at a LIP, and most LIPs are not associated with a volcanic chain. Perhaps the best documented case is the separation of the Kerguelen Plateau from the Ninety-East Ridge and the Rajmahal basalts (Weis et al., 2002; Kent et al., 2002; Coffin et al., 2002). In order to link the basaltic outpourings on mainland India with the Kerguelen Plateau and Broken Ridge a series of ridge jumps are postulated to have occurred as the Kerguelan hotspot drifted slowly to the south (Kent et al., 2002; Antretter et al., 2002). Other models involve multiple plumes (e.g., Coffin et al., 2002). In this paper we draw attention to the links between LIPs, ridges, and transform faults; whereby many of the proposed splits between "plume heads" and "plume tails" may be the result of ridge-reorganizations and transform fault interactions rather than ridge-crossing fixed thermal anomalies. There is a prevalence of "coincidental" relationships between supposed hotspot features and tectonic features such as: 1) the Ninetyeast ridge lies along an extensive offset of seafloor magnetic anomalies – a fossil transform fault, 2) Réunion Island is located on the intersection of an abandoned ridge and a fracture zone, and 3) Mauritius developed on Paleocene fossil spreading centers and were transported away from each other by a fracture zone that lies between them (Hirn, 1993), and 4)the Ontong Java and Shatsky plateaus are thought to have been created at triple junctions (e.g. Sager, 2005).

DISCUSSION

Seamount chains that appear to cross mid-ocean ridges do not require a plume-based model; they can be explained by a combination of ridge dynamics and mantle heterogeneities. Our models demonstrate that volcanism can migrate from one side of a ridge to the other when tensional stress, at and ahead of RTIs, is considered. We further suggest that the nature of the melt sources may also affect seamount-chain geometry. Fertile mantle regions and those at or near their liquidi may produce larger volumes of magma than the surrounding depleted mantle or "hot" mantle (McKenzie and Bickle, 1988).

The recognition that hotspots move relative to one another, and relative to the geomagnetic reference frame, led to the concept of drifting plumes, the predicted consequences of which are no different from those of passive fertile heterogeneity (Silver et al. 2006), . In contrast to mantle-plume models, a stress-controlled mechanism for magma release is better able to explain the rapid volcanism that builds LIPs, and the rapid switching on and off of magmatism along volcanic chains. Furthermore, the size of a fertile heterogeneity is not important, because it is changes in lithospheric stress, and the extension of the lithosphere, that controls and localizes the volcanism. However, fertile anomalies are not required to be small and may exist as large three-dimensional compositional blobs in the mantle such that lithospheric stress concentrations may result in long-term seamount chains.

The melting of fertile patches of mantle requires no additional heat input or heat from the Earth's core to explain even the largest volumes of melt produced. The largest

LIP on Earth is the Ontong-Java Plateau. If the 20-km-thick crust there resulted from draining an area three times larger than the plateau itself (as a result of focusing at the apex of a triple junction), and if 20% melting was involved, then only a 30-km-thick section of the mantle may have been involved. The normal mantle geotherm is usually close to or above the solidus in the depth range of ~30 to ~50 km. Clift (2005) has shown that the subsidence patterns of many oceanic plateaus attributed to plumes are consistent with normal mantle temperatures and not the elevated temperatures expected for plumes. This is consistent with the model we propose here, which attributes ridge-crossing seamount chains and LIPs to the extraction of melt from regions of fertility and does not invoke greatly elevated temperature.

CONCLUSIONS

Many so-called hotspot tracks lie along pre-existing fracture zones and transform faults, or emerge from RTIs. This, along with the inability of propagating cracks to cross ductile zones associated with active spreading ridges, led us to explore mechanisms for the migration of stress conditions as an explanation for the volcanism. A fertile region in the mantle can have effects similar to a hotspot (plume). Finite-element models demonstrate the viability of off-ridge tensional-stress migration associated with ridge-transform intersections (RTIs). Combined with fertile mantle and/or mantle in the nascent melting condition, such areas of tensional stress may create ridge-crossing seamount chains without the need to invoke a mantle plume. This has been shown using both analog models and the reconstruction of the Tristan de Cunha seamount chain.

Many of the geochemical arguments for “plume" compositional components could apply equally well to passive compositional hetereogeneities in the mantle (fertile blobs). Our geometric models do not rule out a fixed thermal plume source for ridge-crossing seamount chains, but they demonstrate that such a model is not required. Differentiating between deep seated mantle plumes and those generated by tensional stresses in the lithosphere is complicated and oft debated. In addition to ongoing debates about the viability of various geochemical parameters for determining the depth of the mantle melt origin (e.g. Foulger et al. 2005;), it has been pointed out that the same tensional forces in the lithosphere that could generate seamounts from shallow melts could also effect where deep-seated melts penetrate the lithosphere. Perhaps the most telling aspect of this debate is that the differentiating between the deep source models and the shallow source models is difficult. On an individual basis, making more actual measurements of stress in the ocean crust and dating more seamounts may tell us which seamount chains have been affected by the lithospheric stresses, but the question of the depth of the magma source is ultimately left to those who study mineral physics and the ability of material to penetrate the phase boundaries of the Earth.

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APPENDIX

Model Parameters and Geometry

Model Type: Two-dimensional plane strain elastic finite element model, program by Gobat and Atkinson (1996).

Model Parameters:

Applied Forces: Applied forces are ridge-perpendicular and applied to the whole of the plate based on the modeled age of the crust. As new ridges are propagated to the SW from the N-S trending ridges, new forces perpendicular to the now NW-SE trending ridges are applied. The basic applied forces are as follows:

Age (m.y.)	Force (N/m)	Age (m.y.)	Force (N/m)
0	2e+12	10	1.23e+11
20	9.17e+10	30	7.1e+9
40	5.1e+8		

Strength: The model consists of material of two end-member strengths, weak and strong. The strong material is 3 orders of magnitude stronger than the weak material. This relationship was based on the strong decoupling expected between ridge material (weak) and oceanic crustal material (strong). Others, (Richardson et al., 1979) have demonstrated that the exact ratio is not important as long as the ratio is greater than one. Because this model was testing end-member conditions the transform was alternately modeled as both weak and strong. If the model of Richardson et al. (1979) holds true for transforms, the exact ratio will not matter, and test models by the authors indicate this to be the case.

Boundary Conditions:

The model is fixed in space along its eastern edge. Numerous configurations were tested to determine the configuration with the least edge effects. By fixing the model on its eastern edge we allow the model as whole to move while still providing a baseline to move against, similar to the apparent movement of the entire South Atlantic basin away from the pinned African plate.

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Figure 1: Cartoon of a ridge-crossing seamount chain geometry in the Atlantic (after Sleep, 2002b).

Figure 2: Results of finite-element modeling of the nascent-melting case. Panels show a series of 2D models of a reorganizing ridge. Background colors indicate maximum stress intensity, warmer colors indicate larger stresses, white and black bars indicate maximum and minimum stress vectors (white: compressional, black: tensional). Adjacent figures show modeled ocean ages and approximate location of seamounts caused by tensional stress ahead of ridge-transform intersections.

Figure 3: Time series for a conceptual model of a ridge and a fertile mantle region migrating with respect to a fixed point on the eastern (African) plate. Ridge geometry and motion is taken from Sleep (2002b).

Figure 4: Reconstruction of Atlantic plate motions and ridge location for the last 80 ma using Mueller et al. (1997), age grid, Smith and Sandwell (1997) gravity data, and O'Connor et al. (1999) hotspot ages. Plate location relative to a fixed frame is modeled based on seamount production at the ridge and a fixed fertile blob (designated by an open circle), the circle is held fixed relative to the black and white box around each time period. Note that most of the seamounts are created on the ridge.

Figure 5

5a: Mapview of the large area of potential tensional stress ahead of a ridge-transform intersection (RTI) and the potential for a seamount of significantly younger age to be emplaced into older oceanic crust.

5b: Mapview of the position of a fertile mantle blob that might result in seamounts created via decompression melting both off the ridge ahead of the RTI and at the ridge.

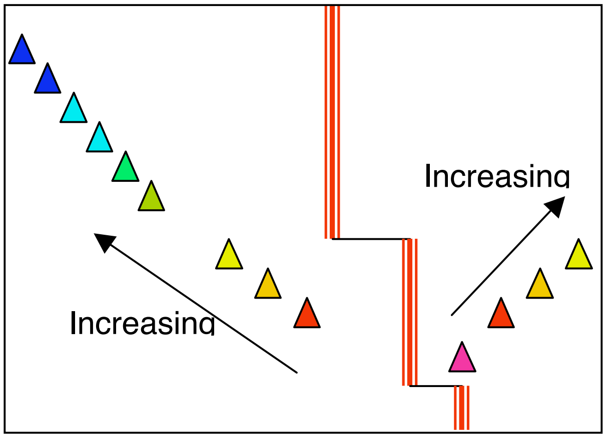
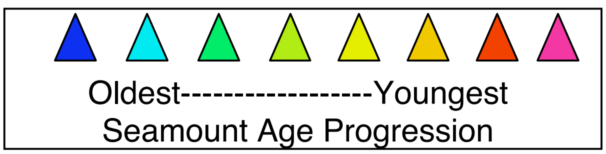


Figure 1: Geometry of Seamount Chains in the South Atlantic [modified from Sleep 2002]



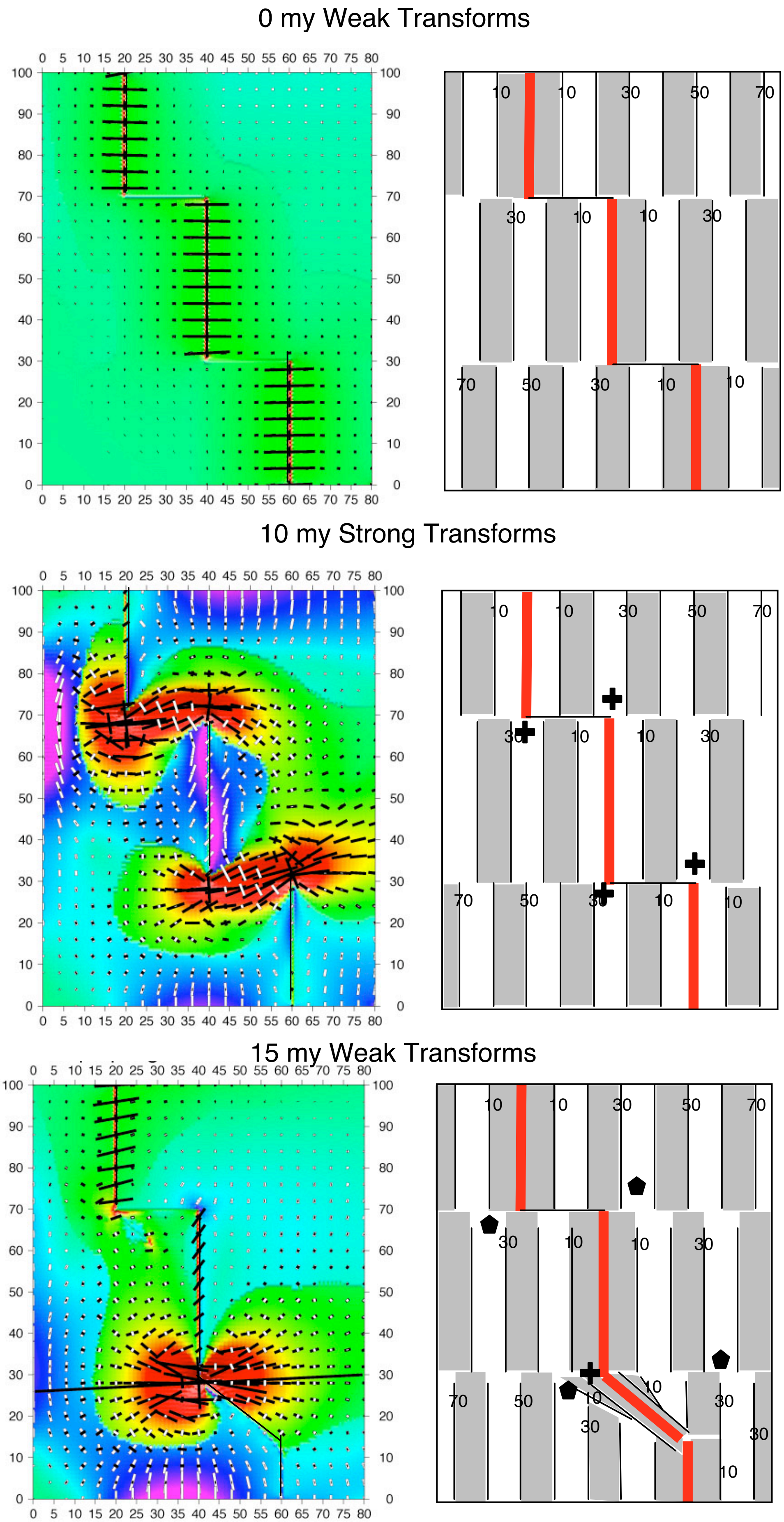
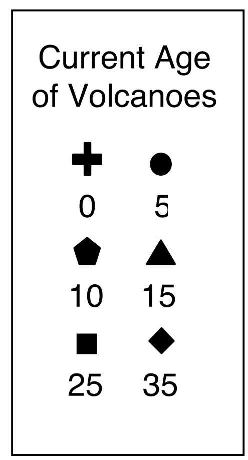


Figure 2: Finite element models and geodynamic interpretation of ridge propagation over a sub-solidus mantle



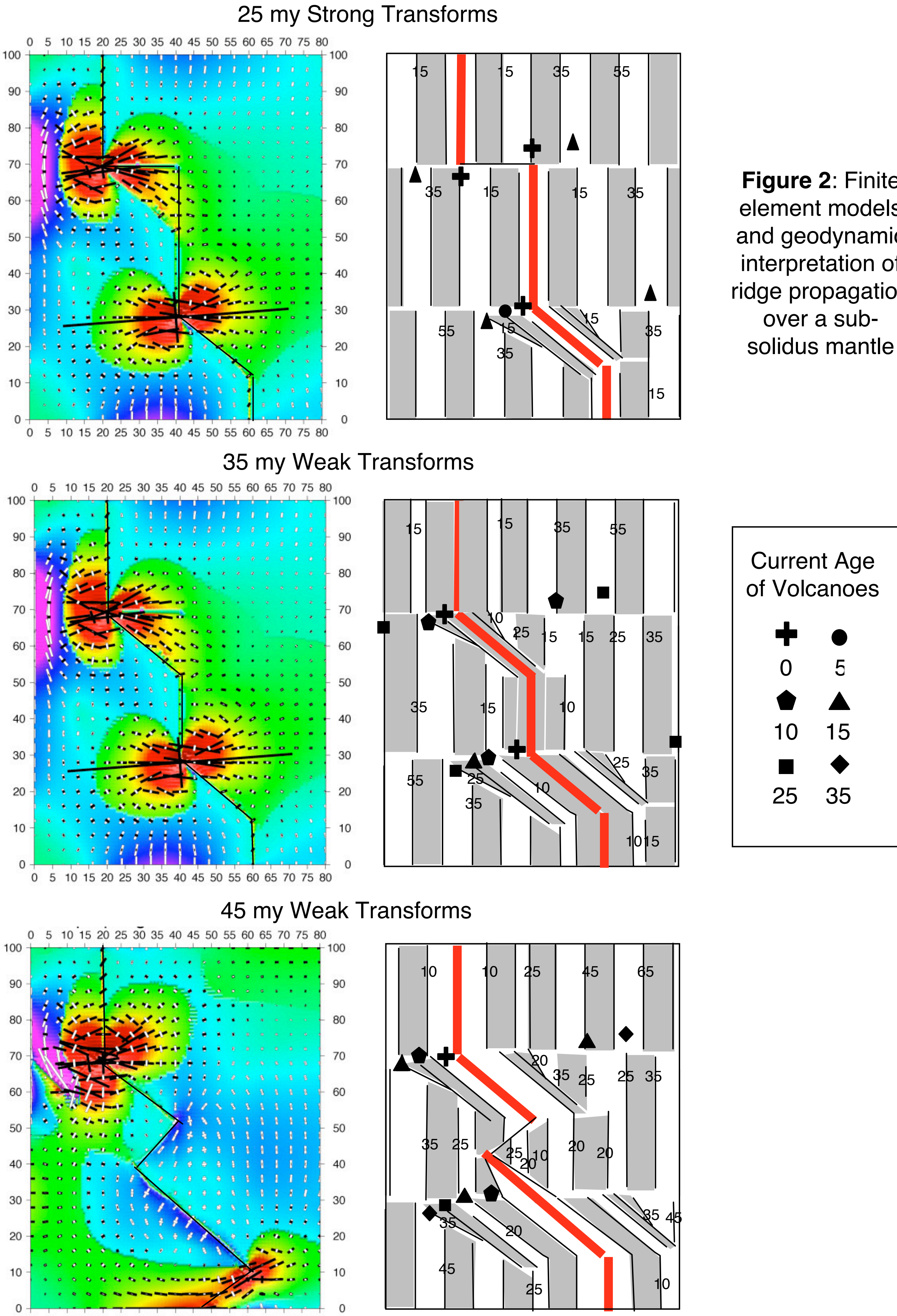


Figure 2: Finite element models and geodynamic interpretation of ridge propagation over a sub-solidus mantle

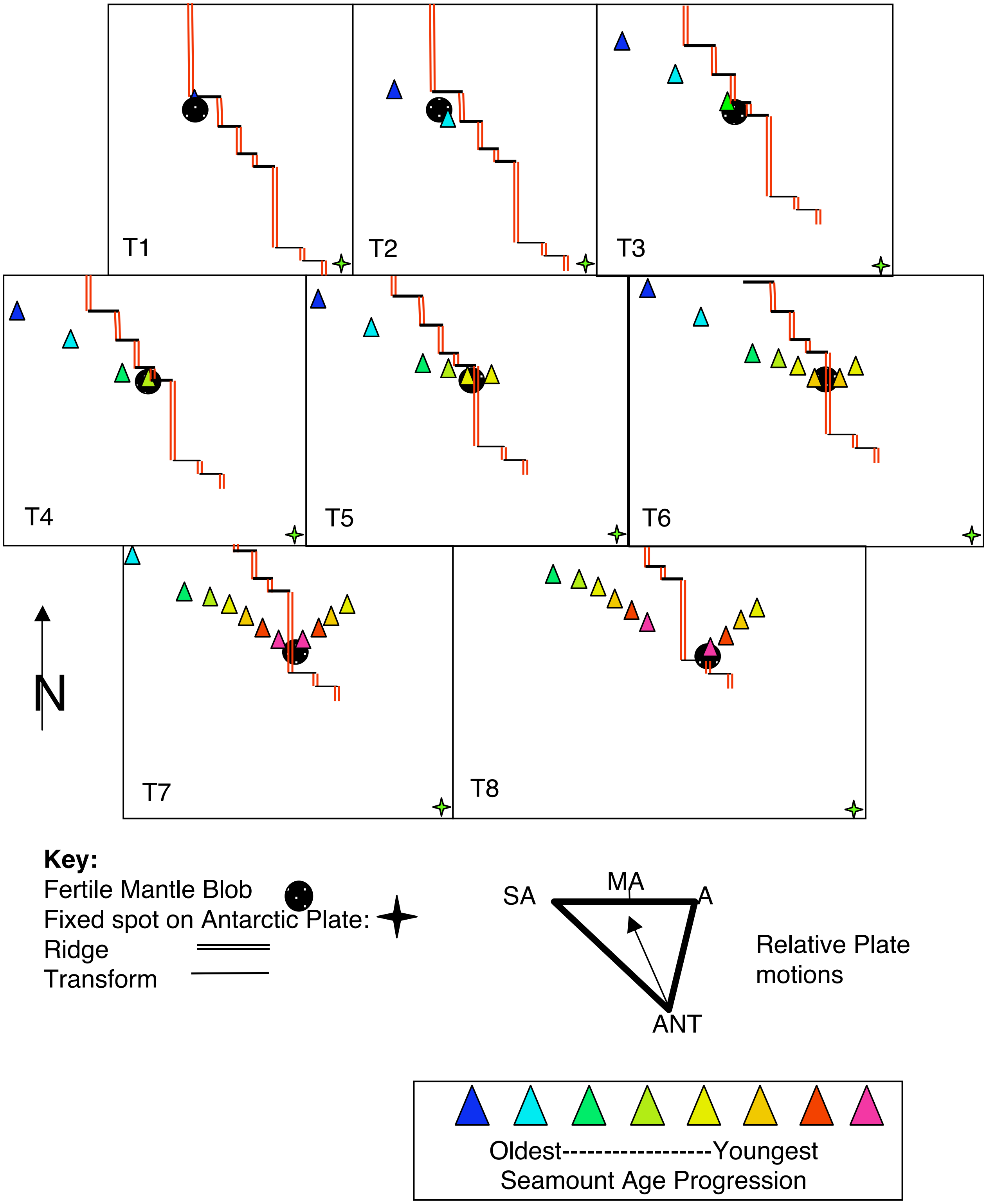


Figure 3: Fertile mantle blob model of Atlantic region

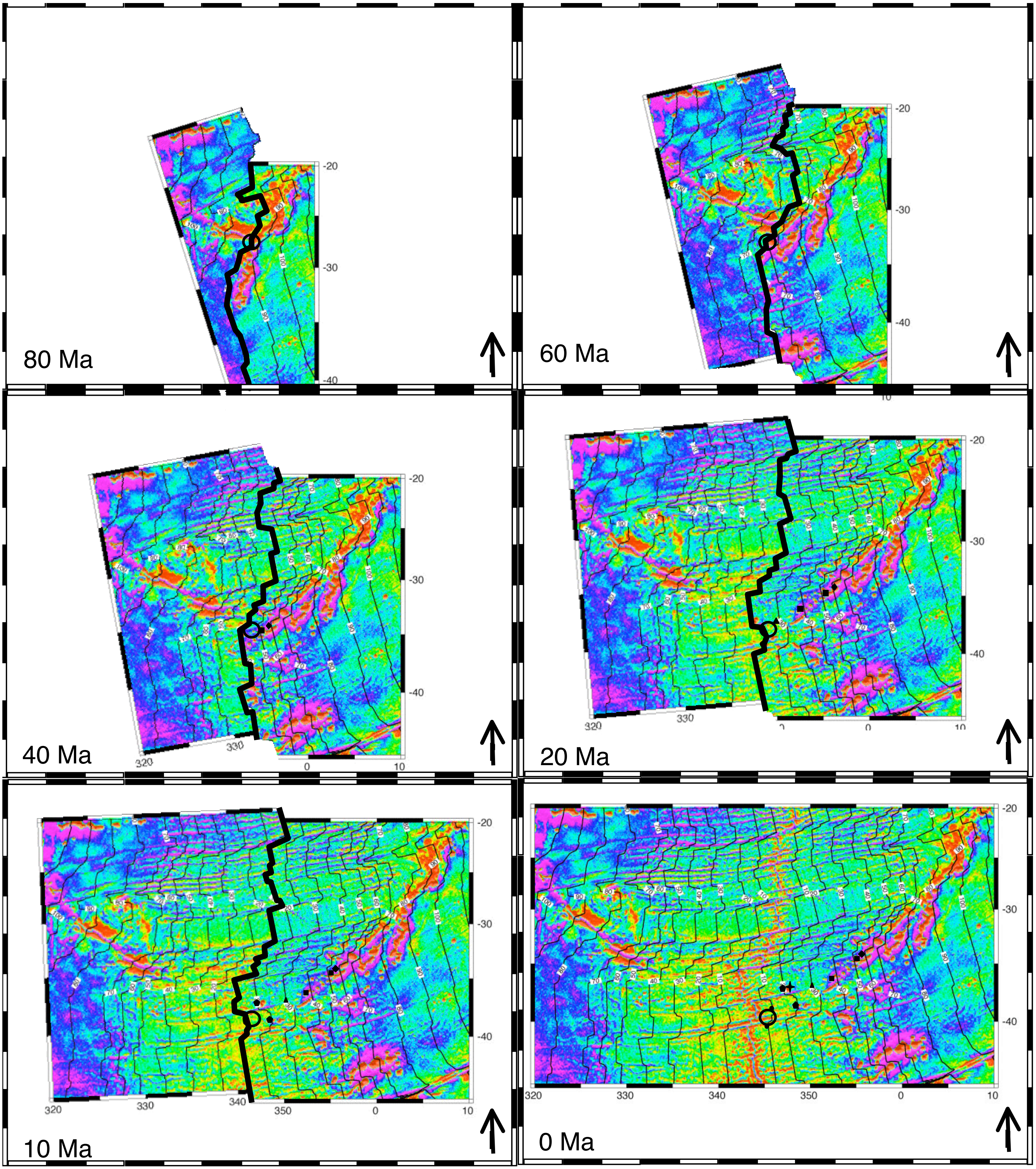


Figure 4: South Atlantic reconstruction with dated seamounts and proposed location of fertile blob

0 10 20
30 40 50

Approximate age of Tristan chain seamounts in million years: O'Connor et al[37]

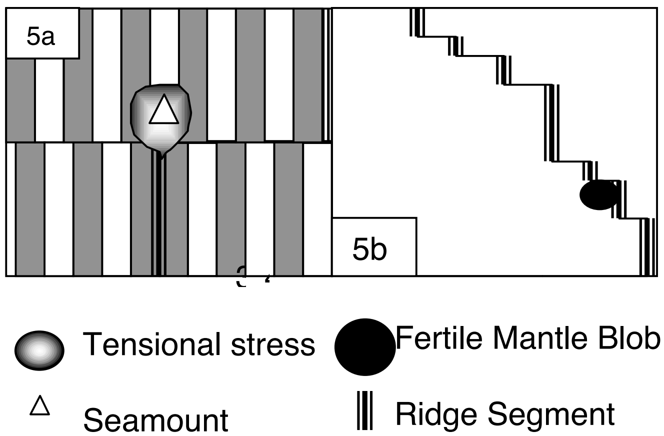


Figure 5: Age relationships