Earthworks
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Research Update No. 18, January 2021

The early opening of the South Atlantic Ocean: As simple as possible, but no simpler.

Introduction

The possible fit of South America against Africa was the first trigger than made scientists start thinking that this may be more than a coincidence. The theorem of plate tectonics emerged some 50 years after Alfred Wegener's early ideas and the South Atlantic Ocean has become a widely-recognised icon for how the continents have moved. When I started working with paleo-reconstruction I, too, assumed that this system was well-known and turned my attention to the uncertainties of the Indian Ocean. With the benefit of the wisdom gained from this experience, it is now clear that over-simplifying the story of the South Atlantic opening can be a barrier to understanding the processes that have played out there at a scale that is useful to exploration-sized areas.

The main over-simplification is that Africa and South America are simply two rigid plates bordering the ocean to its east and west over a distance of 4900 km. Our model has only 1700 km of this distance being that simple, with the two 'core' plates (**Zone E**, figure 1). To the north of them (**Zone F**) there is 500 km of conjugate margin with geometrical changes occurring probably within both Africa (Cameroon) and South America (Borborema, NE Brazil).

In **Zone D** (500 km wide) the separation of the two continents is complicated by a sliver of continental material that moved independently of both South America and Africa in the earliest phases of separation before becoming attached to South America as the present day Sao Paulo Plateau.

Zone C (1100 km), meanwhile, lies between two major faults crossing Africa that we think moved dextrally at about the time of the widespread plate reorganisation, circa 130 Ma. On the South America side, there is a possibility that a plate we have called Uruguay moved slightly with respect to the rest of South America with a contact in the region of Porto Alegre. Our most recent thinking is that the early mid-ocean ridge over this distance included some continental fragments that rode the ridge, Iceland-like, until well into the Upper Cretaceous before rotating anti-clockwise and joining South America as the Rio Grande Rise.

Zone B (1100 km) has complex geometry south of Rio de la Plata facing a single block on the Africa side. The excess length of the South America margin (about 180 km) compared to Africa is removed by closing the Salado and Colorado rift basins and so bringing the escarpment on the north flank of the Malvinas plateau into registration with the Agulhas fault off South Africa.

The story from **Zone A** (south of the Falklands-Agulhas FZ) is discussed elsewhere.

The following table and six figures attempt to summarise all this.

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Delft, 2021 January 26

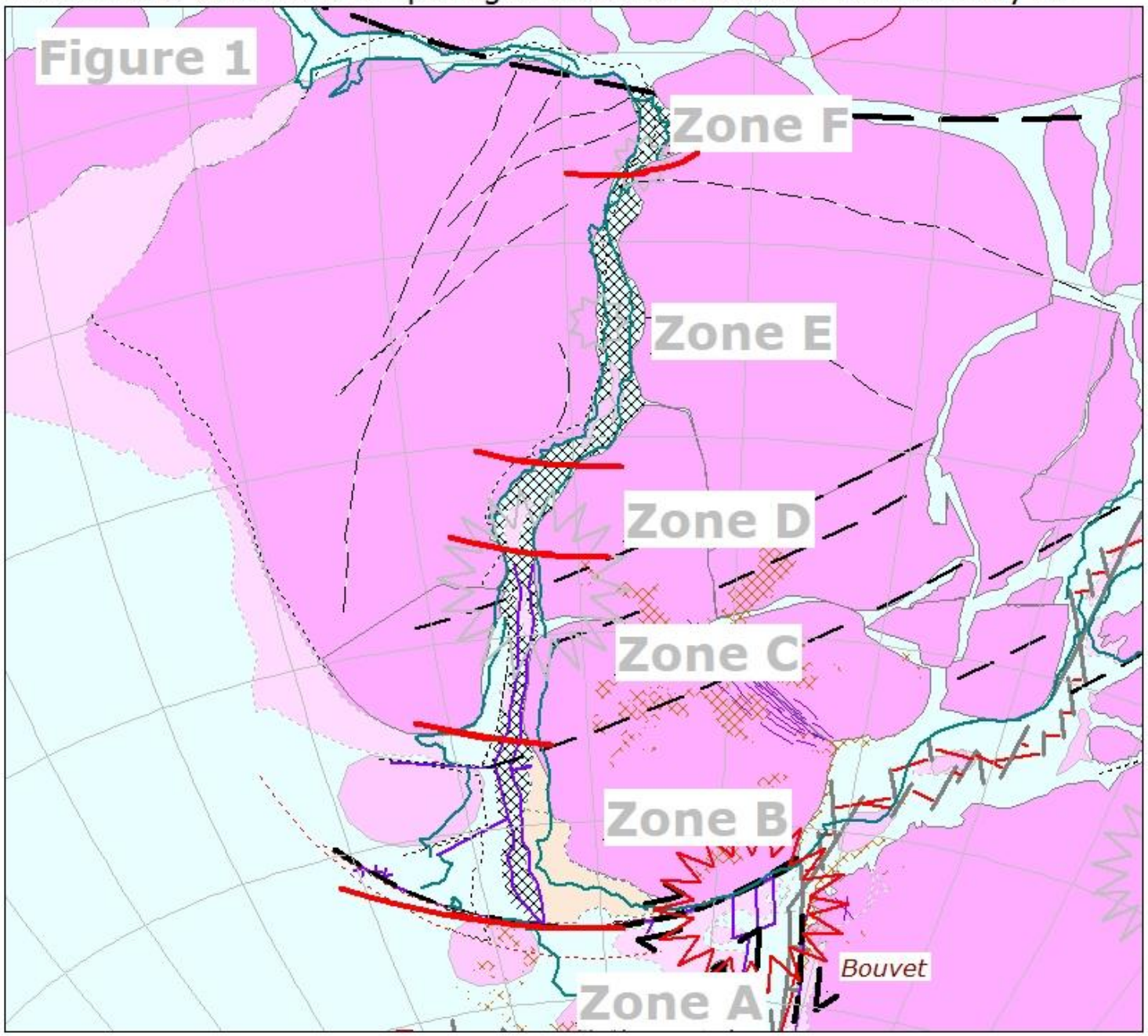
The Early Opening of the South Atlantic Ocean

A tentative summary based on model CR20ABJO (version 2021 January 26)

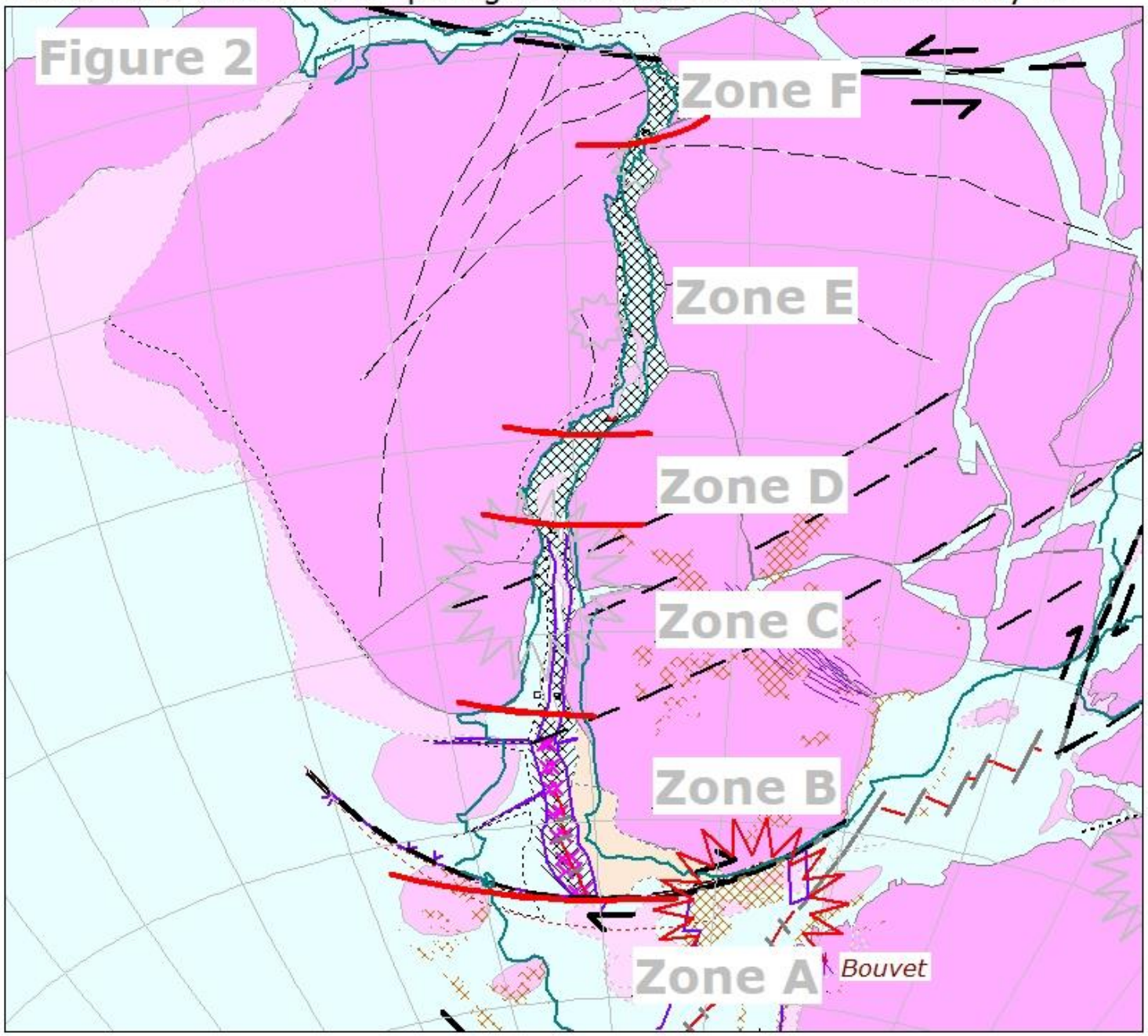
	Before 157.5 Ma (Figure 1)	**157.5 to 144.32 Ma** (Figure 2)	**144.32 to 135.62 Ma** (Figure 3)	**135.62 to 126.11 Ma** (Figure 4)	**126.11 Ma to 117.0 Ma** (Figure 5)	**After 117 Ma** (Figure 6)
Zone F: Cameroon and NE Brazil to trans-Africa fault	No action	Potiguar basin? Reconcavo? Sinistral movement on trans-Africa fault?	No action	No action	Crustal extension; N Cameroon moves W against rest of Africa?	New spreading direction from 117 Ma initiates ocean growth that extends progressively W into the Equatorial Atlantic.
Zone E: Main section, Africa vs South America directly (no smaller fragments)	No action	No action	No action	Crustal extension starts at about 136 Ma.	Crustal extension; salt basin (yellow) develops at about 113 Ma [see footnote].	Salt basin sundered; ingress of ocean water from S; ocean growth starts with the new spreading direction.
Zone D: São Paulo plateau	No action	No action	No action	Eruption of Parana-Etendeka basalts at 135 Ma; crustal extension W of São Paulo plateau.	Lacustrine carbonates deposited in the Santos basin, west of the São Paulo plateau, prior to salt deposition.	São Paulo plateau leaves Africa with crustal stretching between it and Africa delaying onset of ocean growth until Early Albian, ¬112 Ma.
Zone C: Rio Grande Rise. Florianopolis to Rio de la Plata and Henties Bay to Orange River mouth	No action	No action	Crustal extension	Volcanic extrusion from 135 Ma onto emerging mid-ocean ridge atop Tristan plume head. Dextral movement on Mwembishi shear zone across Africa.	Mid-ocean ridge (1000 x 250 km) separate from both continental margins. Rio Grande Rise atop the Tristan plume head, Iceland-like..	Ocean growth with mid-ocean ridge separate from both continents. Ridge drifts slowly to W of Tristan plume head. Walvis Ridge plume trail develops between it and Angola.
Zone B: northern Patagonia and South Africa S of the Orange River.	No action	Onset of crustal extension towards end of Jurassic (145 Ma).	E-W Crustal extension; N-S opening of Salado and Colorado rifts	Seaward-dipping reflectors emplaced, followed by ocean growth.	Ocean growth direction close to that adopted everywhere after 117 Ma direction change.	Ocean growth direction very similar to that further north after AFR-SAM pole change at about 117 Ma.
Zone A: South of the Falklands/Malvinas-Agulhas Fracture Zone.	Early rifting on Agulhas FZ and in Outeniqua basin	Crustal extension between Malvinas plateau and Maurice Ewing Bank.	Crustal extension continues between Malvinas plateau and Maurice Ewing Bank.	Ocean growth starts to E of Maurice Ewing bank (Natal Valley).	Ocean growth continues E of Maurice Ewing Bank into Cretaceous Quiet Zone.	Malvinas plateau, now fixed to all South America, moves W along Agulhas FZ; eruption of Agulhas Plateau volcanics at about 100 Ma above (rejuvenated?) Bouvet plume head.

Note: The timing of disruption of the short-lived salt basin (circa 113 Ma from stratigraphy) probably coincides with the major change in spreading direction. In the model this takes place at 117 Ma, based on magnetic anomaly timings in GTS2016. GTS2020 timings would place this event about 4 myr younger.

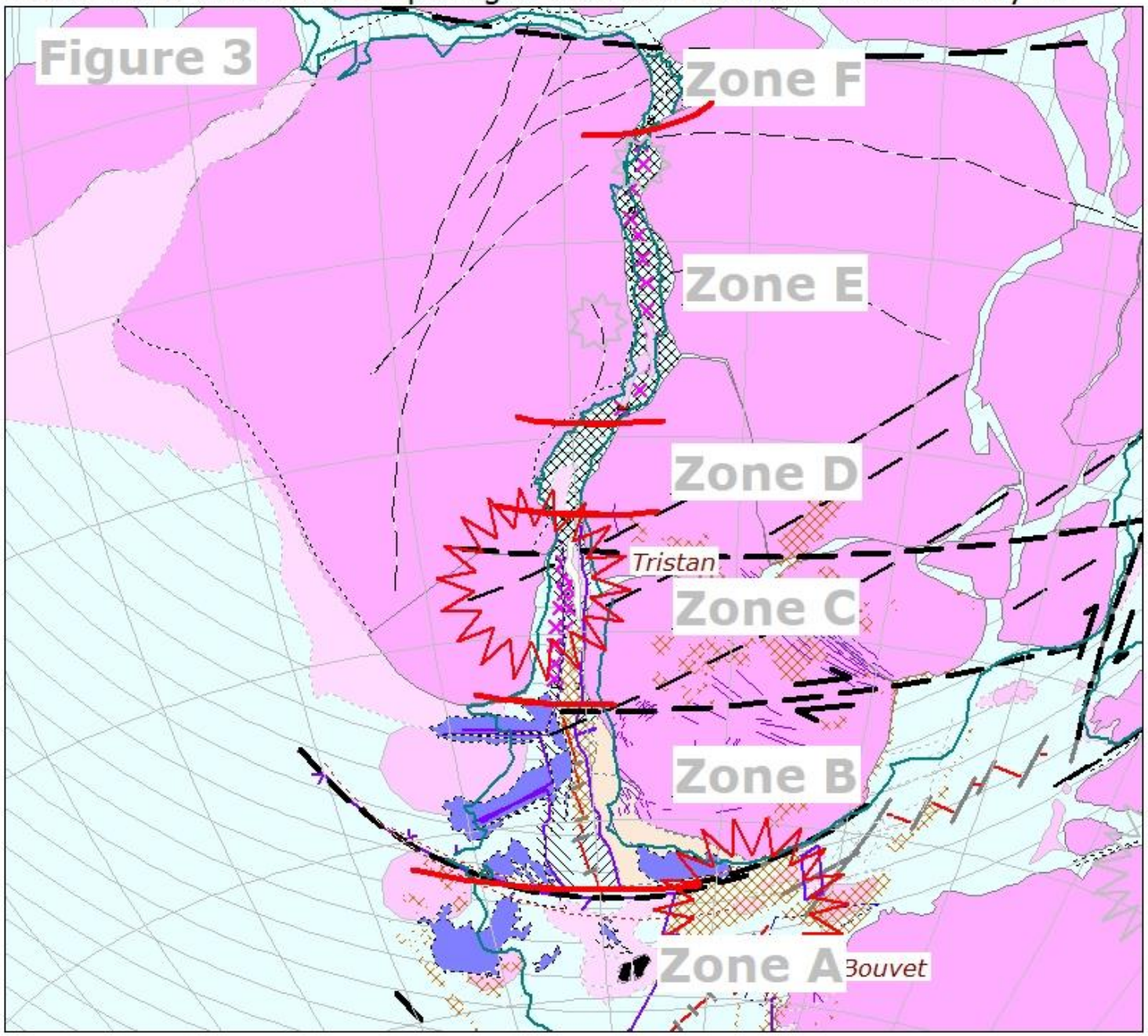
157.50 Ma :: CR20ABJO :: Opening of the South Atlantic :: 2021 January 26



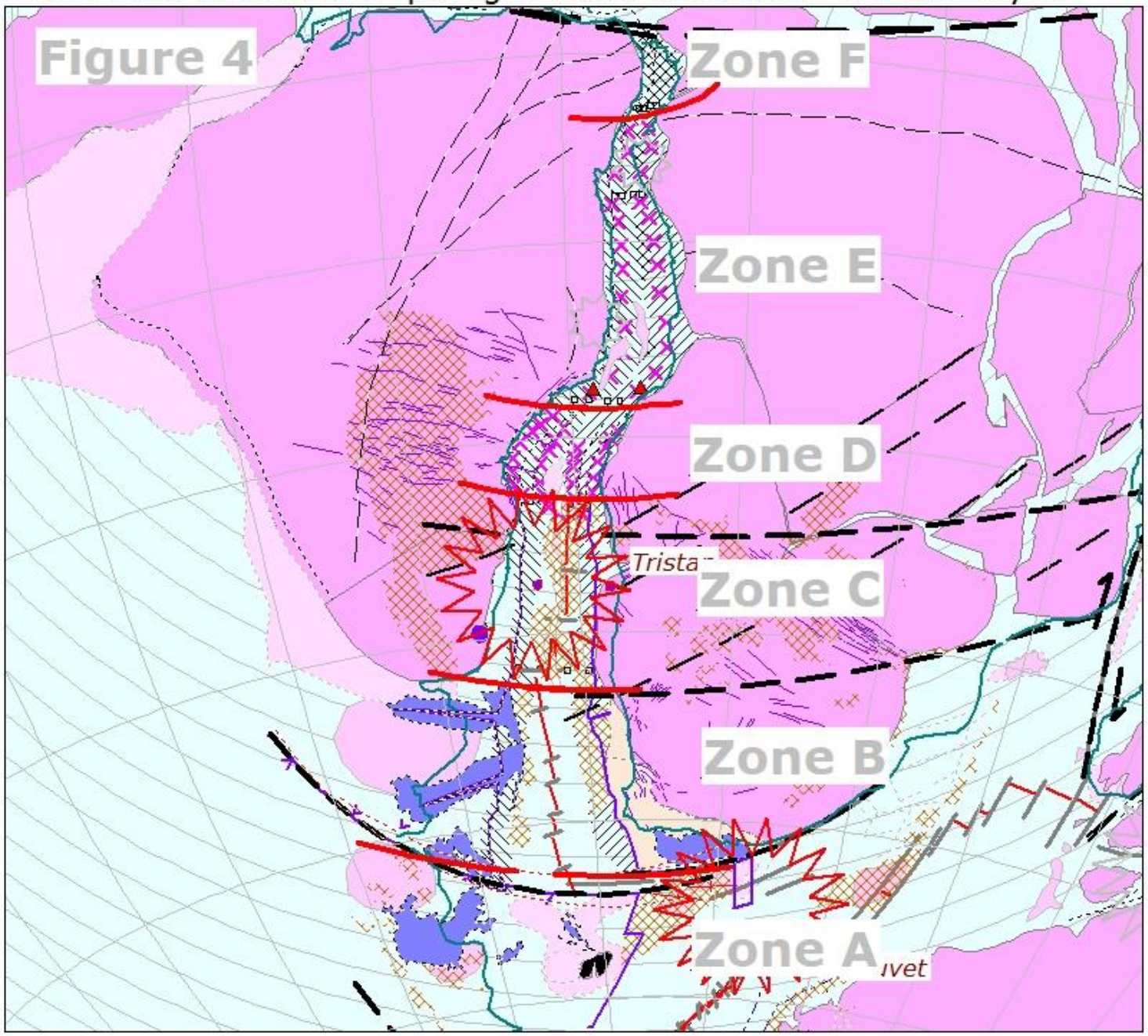
142.32 Ma :: CR20ABJO :: Opening of the South Atlantic :: 2021 January 26



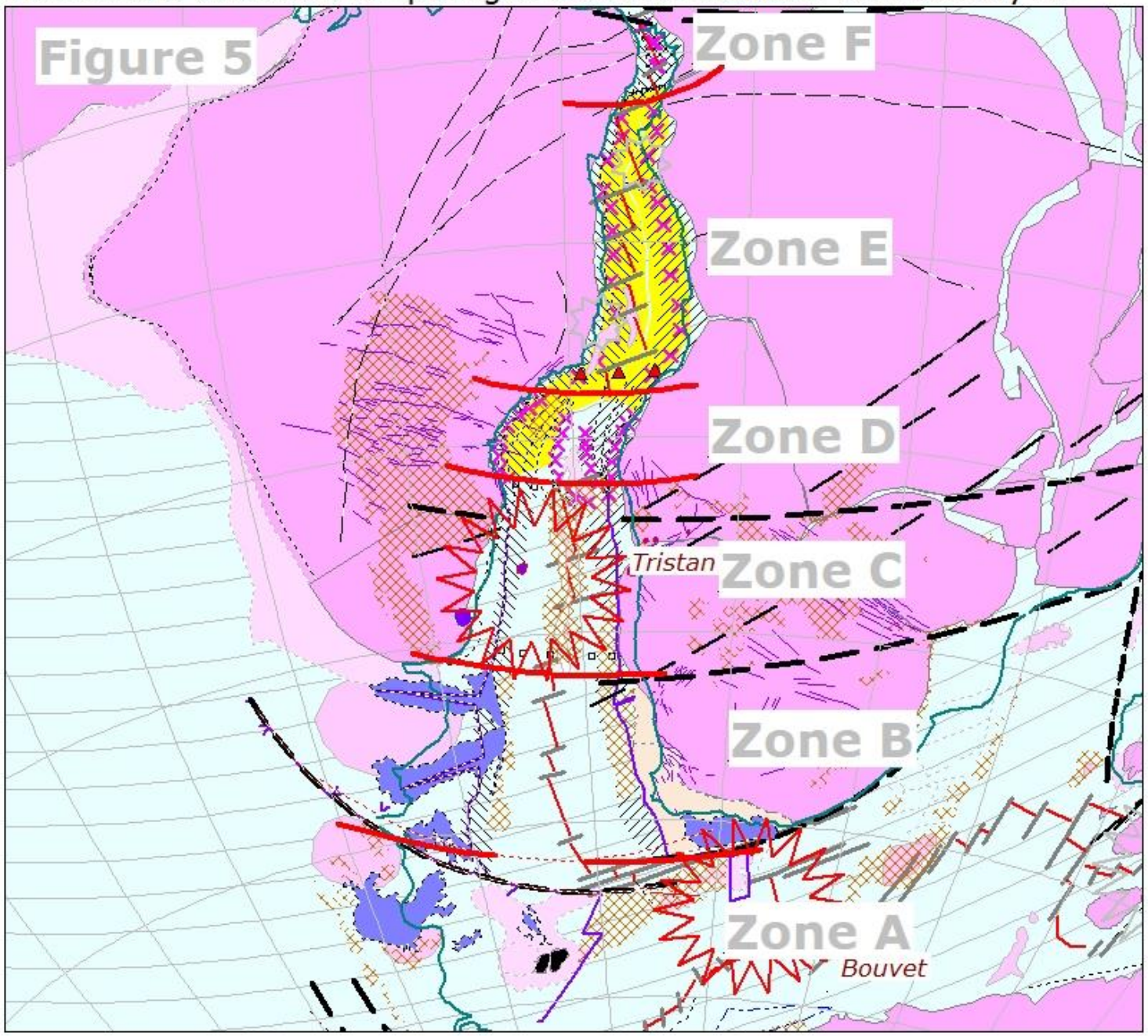
135.62 Ma :: CR20ABJO :: Opening of the South Atlantic :: 2021 January 26



126.11 Ma :: CR20ABJO :: Opening of the South Atlantic :: 2021 January 26



117.00 Ma :: CR20ABJO :: Opening of the South Atlantic :: 2021 January 26



100.00 Ma :: CR20ABJO :: Opening of the South Atlantic :: 2021 January 26