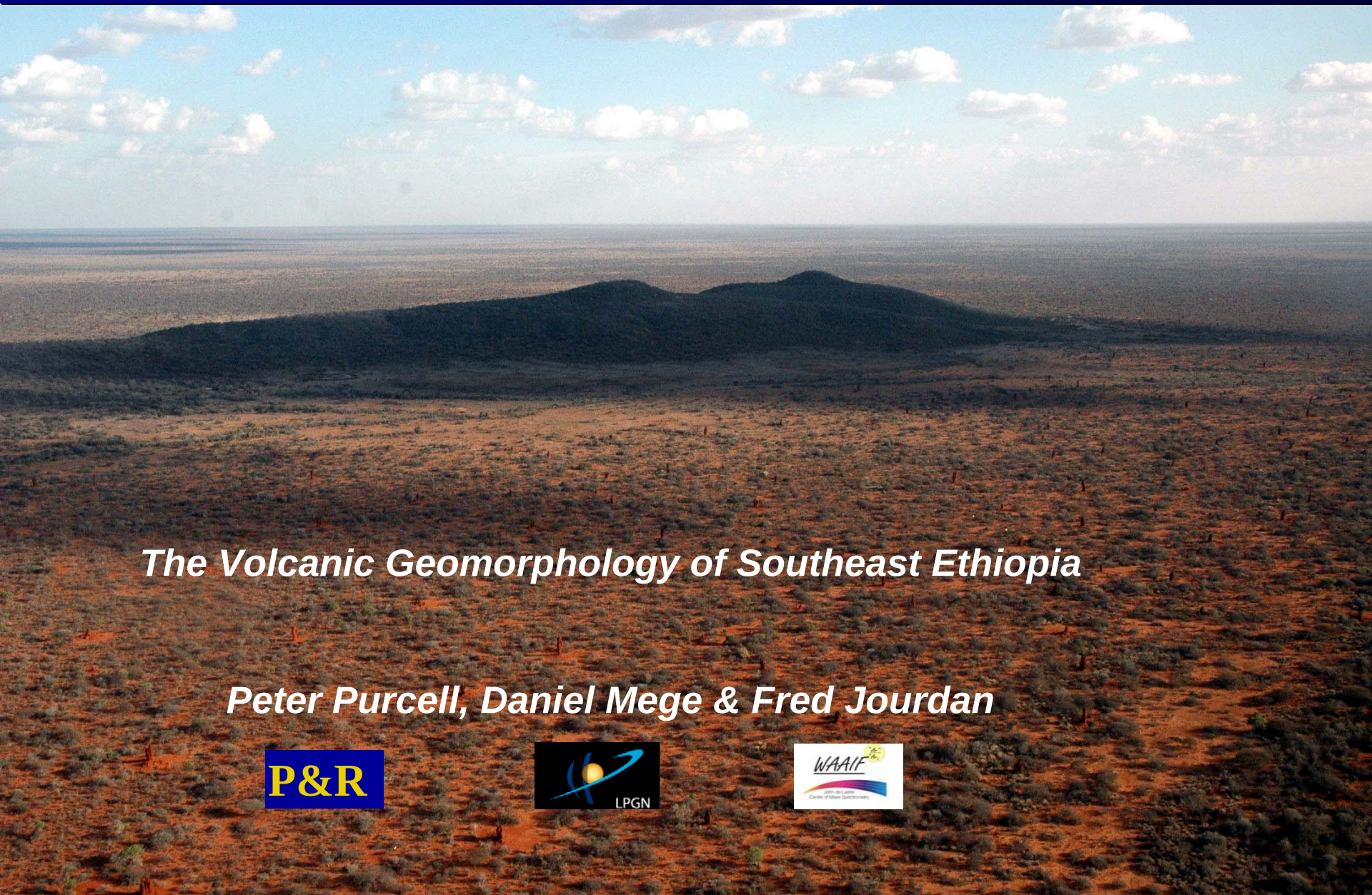

The Volcanic Geomorphology of Southeast Ethiopia

Peter Purcell, Daniel Mege & Fred Jourdan

P&R LPGN WAAIF

Regional setting

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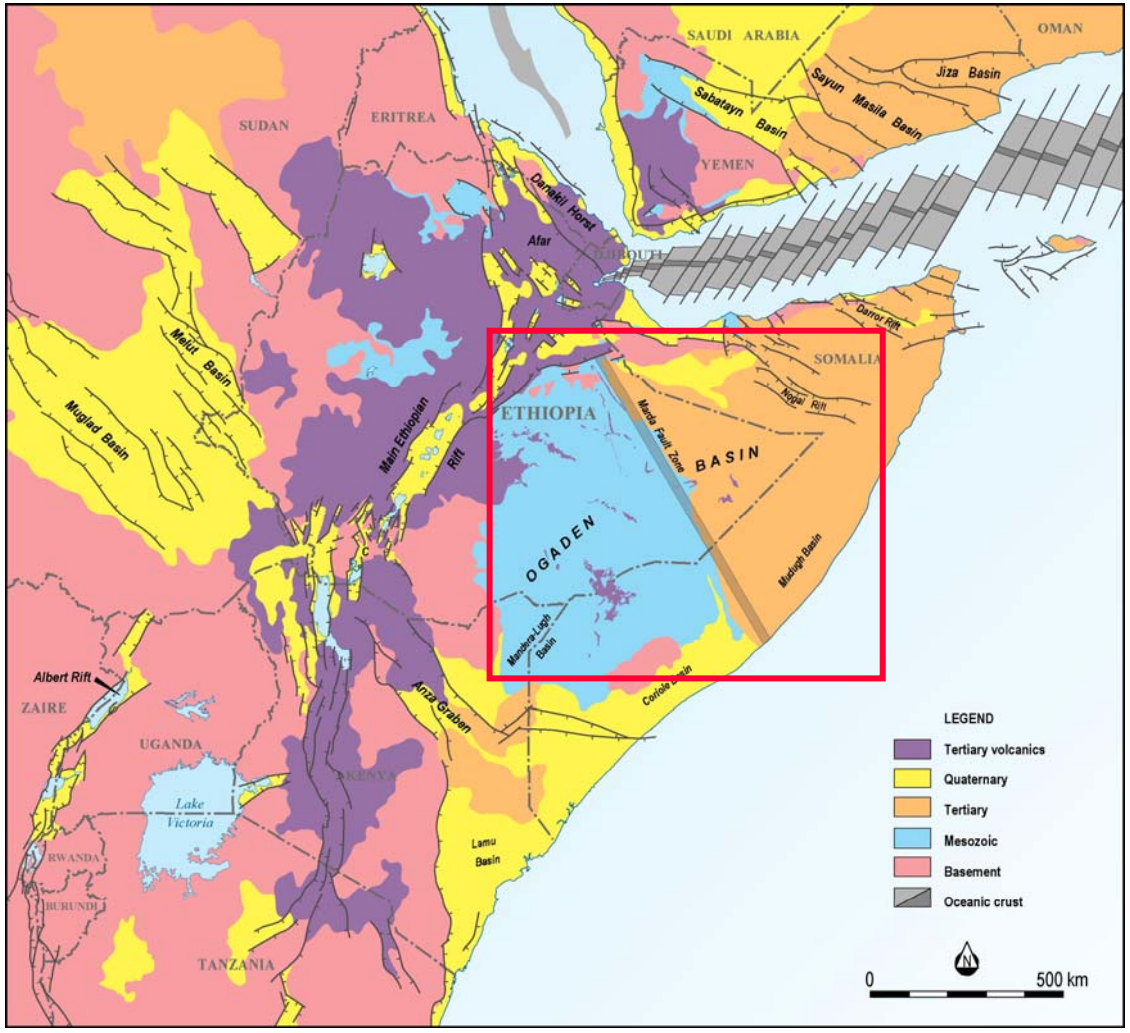

- The volcanic geomorphology of Ethiopia is asymmetrical relative to the Ethiopian Rift Valley and Afar
- Tertiary volcanics are aerially and volumetrically much greater on the western side of the rift
- The University of Nantes project, led by Dr Daniel Mege aims to map and date the volcanics in southeast Ethiopia,, and to understand their origin and the tectonic links to the Tertiary rifting in Ethiopia and adjacent regions
- Work to date has combined mapping of satellite imagery with field checks and sampling, petrographic analysis and age-dating, and integration of magnetic survey data and subsurface information from oil and water bores
- Tertiary volcanism is seen to be aerially far more extensive than previously recognized and in regions remote from the main Tertiary rifts.

Outline of Presentation

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Dr Daniel Mege, University of Nantes, eastern Ogaden, 2008

1. Introduction
2. Examples of volcanics in the Ogaden region, SE Ethiopia
3. Examples of influence of volcanics on local culture
4. New map of volcanics, SE Ethiopia
5. Magnetic mapping of buried volcanic flows
6. Surface and subsurface distribution of volcanics
7. Paleogeographic setting of main volcanic episode
8. Status of project

ETM image, SE Ethiopia, showing volcanic complexes

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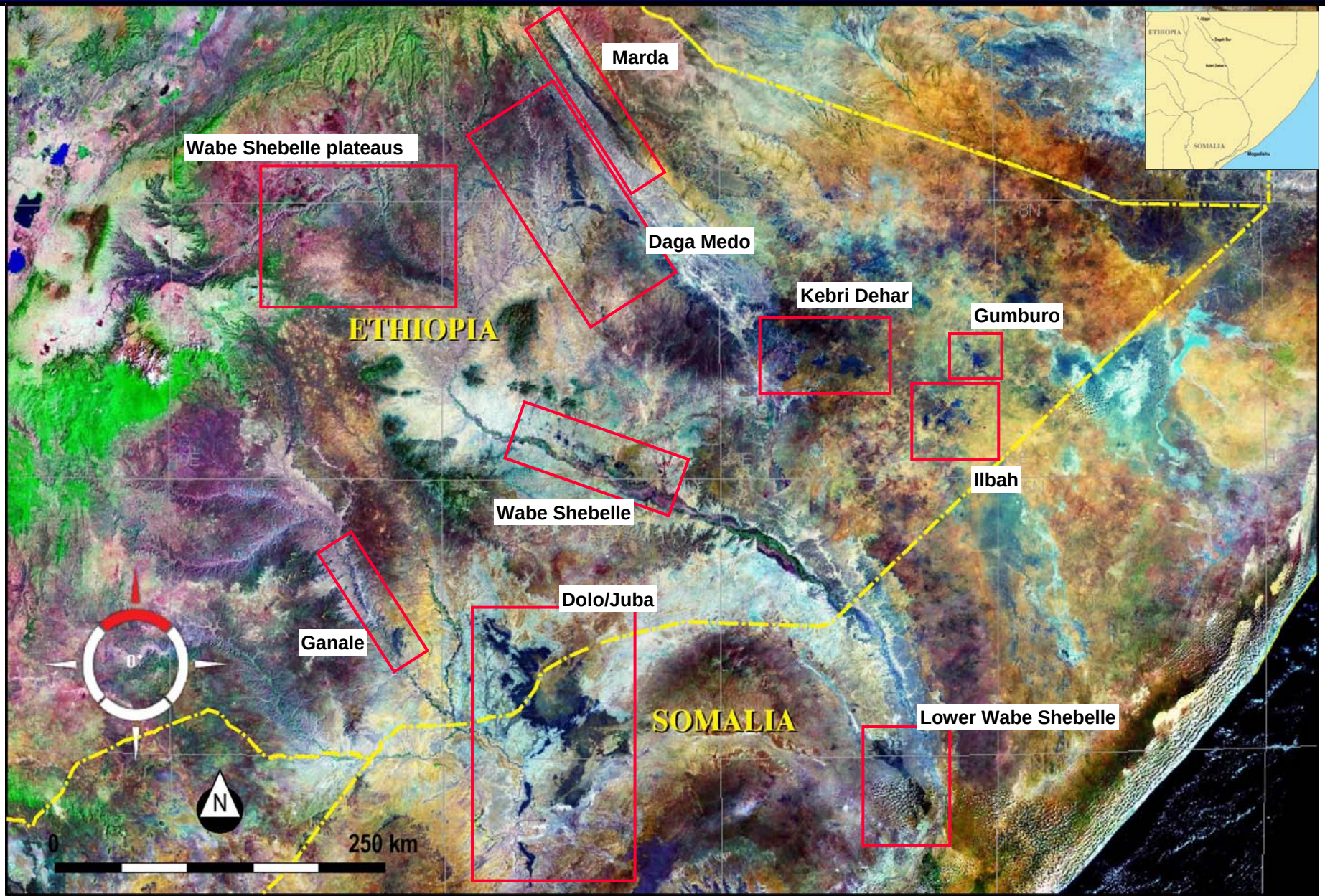

Surface forms of Tertiary volcanics, SE Ethiopia

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Volcanics in SE Ethiopia occur as

- broad volcanic plateaux
- isolated hill complexes
- linear outcrops, notably along the Marda Fault Zone, and
- meandering ribbons of exhumed paleo-canyon basalt fill

Ancestral Wabi Shebelli canyon-fill

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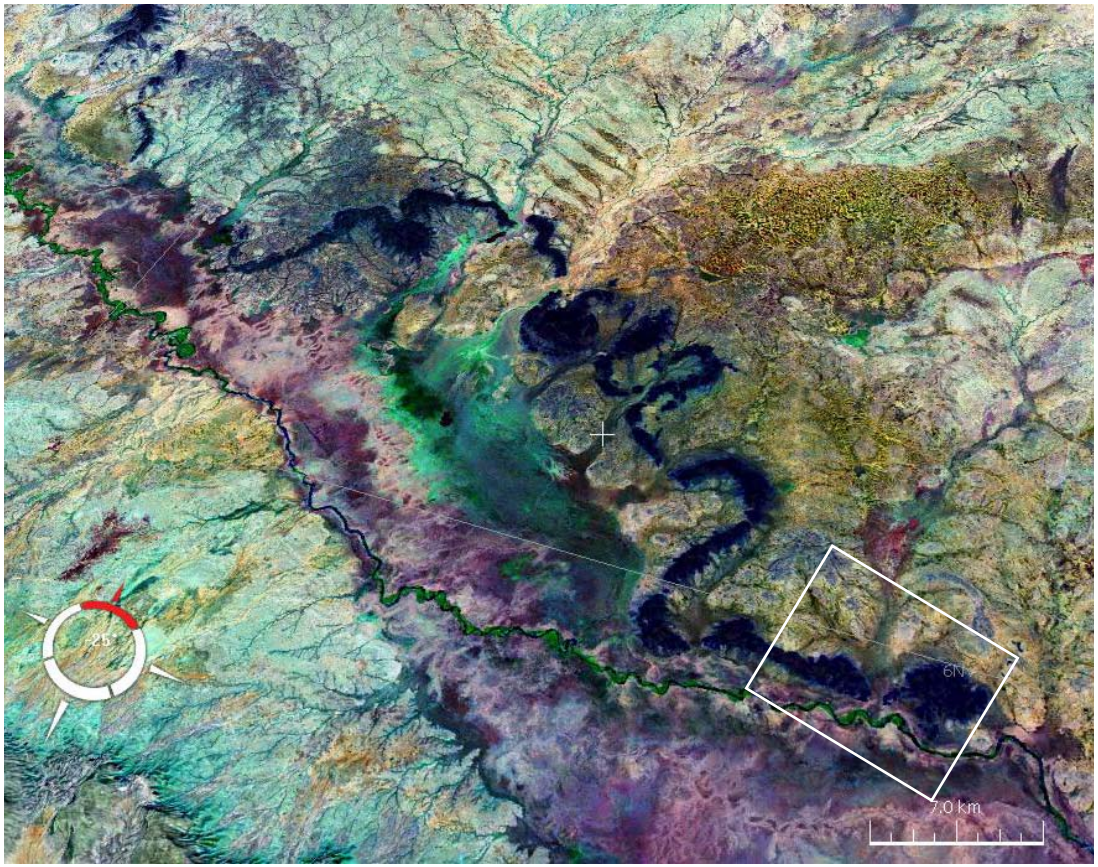
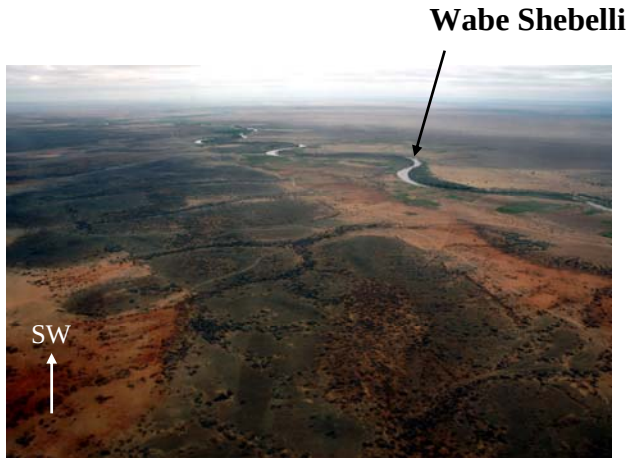


- Meandering volcanic hills along the Wabe Shebelli, northwest of Gode, are remnants of basalt flows which filled the ancestral Shebelli River.
- The ancestral river was much larger than the current river: (width, 500 m v 100 m; meander length, 5 km v 1 km; and higher sinuosity (2 v 1.7)
- The Sepik River in northern Papua New Guinea is of similar size to the ancestral Wabe Shebelle



Ancestral Wabi Shebelli canyon-fill

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- The volcanic hills vary to 40 m high, sometimes with distinct scarps but commonly as broad, low mounds, clearly distinguished by the grey-brown colour on the generally red sand plain
- The outcrops can be traced relatively continuously for over 200 km (thalweg length) and isolated erosional remnants occur beyond this.
- The surface is commonly fine grained pebble and dust, with scattered large rounded boulders.
- A single age-date of 27 My indicates a Late Oligocene age

Daga Medo complex

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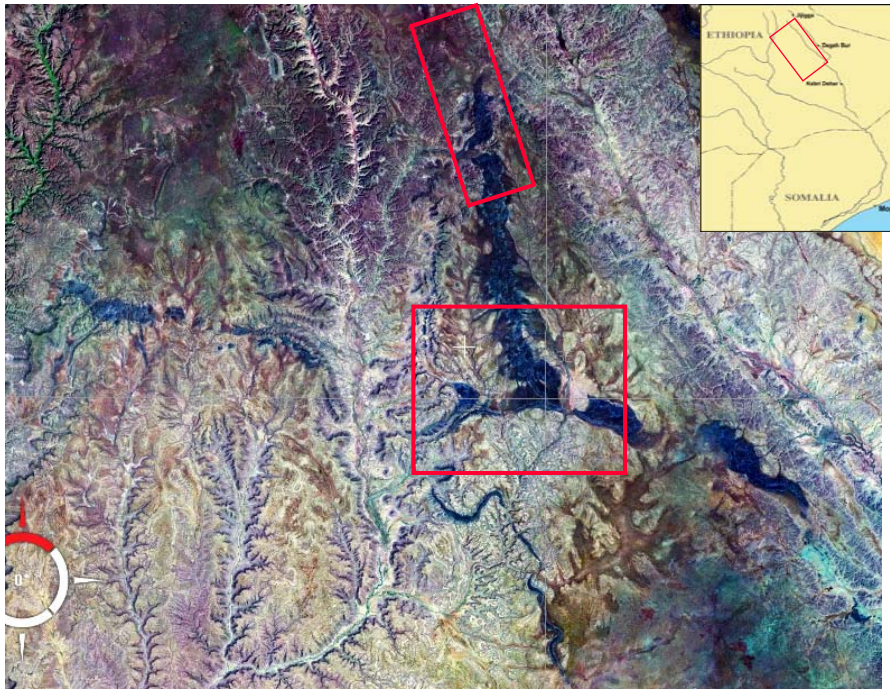

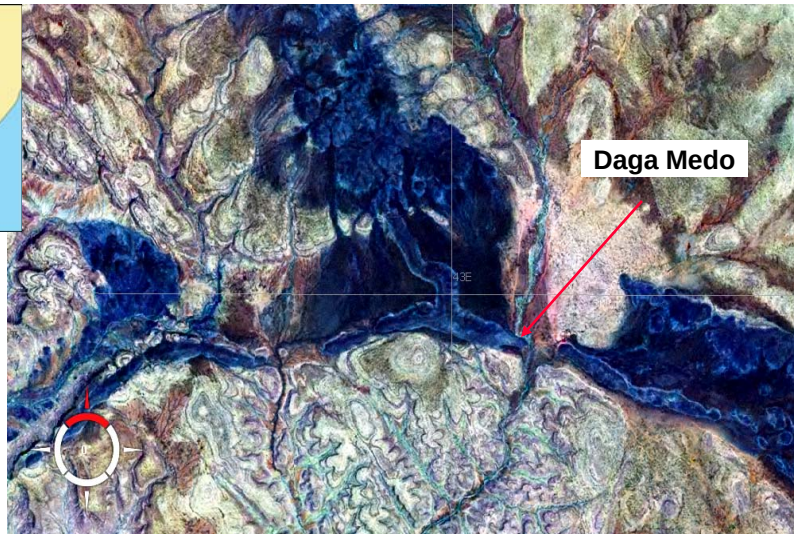

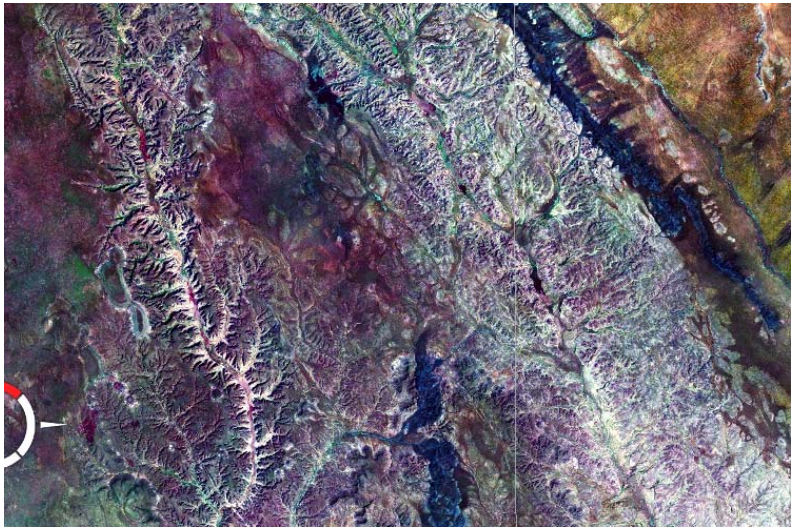

- The Daga Medo volcanic complex, located in the central Ogaden region, consists of a a main north/south vent system and extensive flows
- A main flow to the south has a marked bifurcation (see upper right) , with eastward and westward flows that turn southeastward and continue for over 100 km.
- The Daga Medo flow also appears to have a northern branch (bottom right)..

Daga Medo meandering complex

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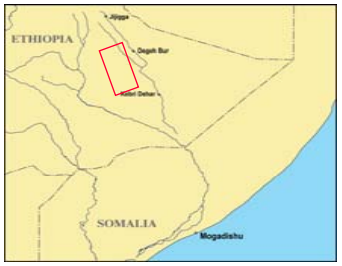

- The western Daga Medo flow extends southeast over 120 km across the Ogaden in a series of markedly meandering outcrops 20-40 m high
- The hills have formed by exhumation of the basalt ‘ribbon’ formed when lava flows filled a meandering river channel cut into the Cretaceous sediments of the Ogaden Basin.

Towns located in volcanic areas

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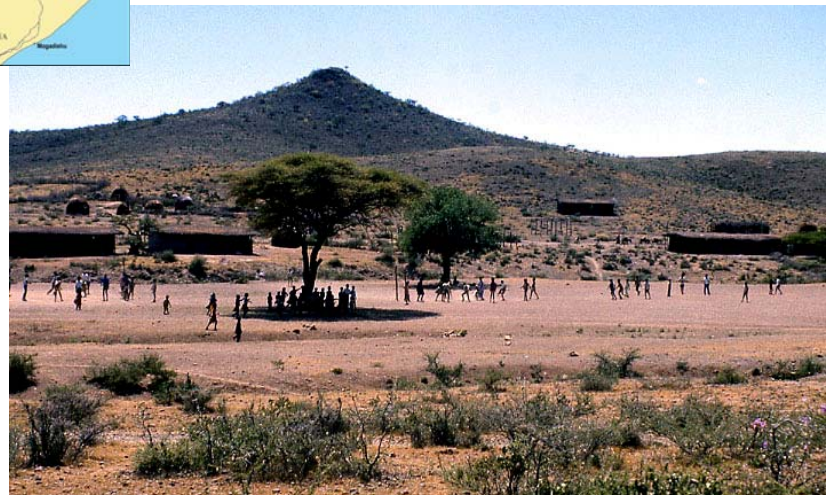

- The volcanic complexes of the central Ogaden region have influenced the location of several main towns
- Daga Medo (above left) is built on top of a major recent flow which has caused a marked deflection of the river
- Fik (right, top and bottom) is located west of Daga Medo within a broad basalt complex with prominent cones and broad rolling hills.

Ilbah Hills volcanic complex, eastern Ogaden region

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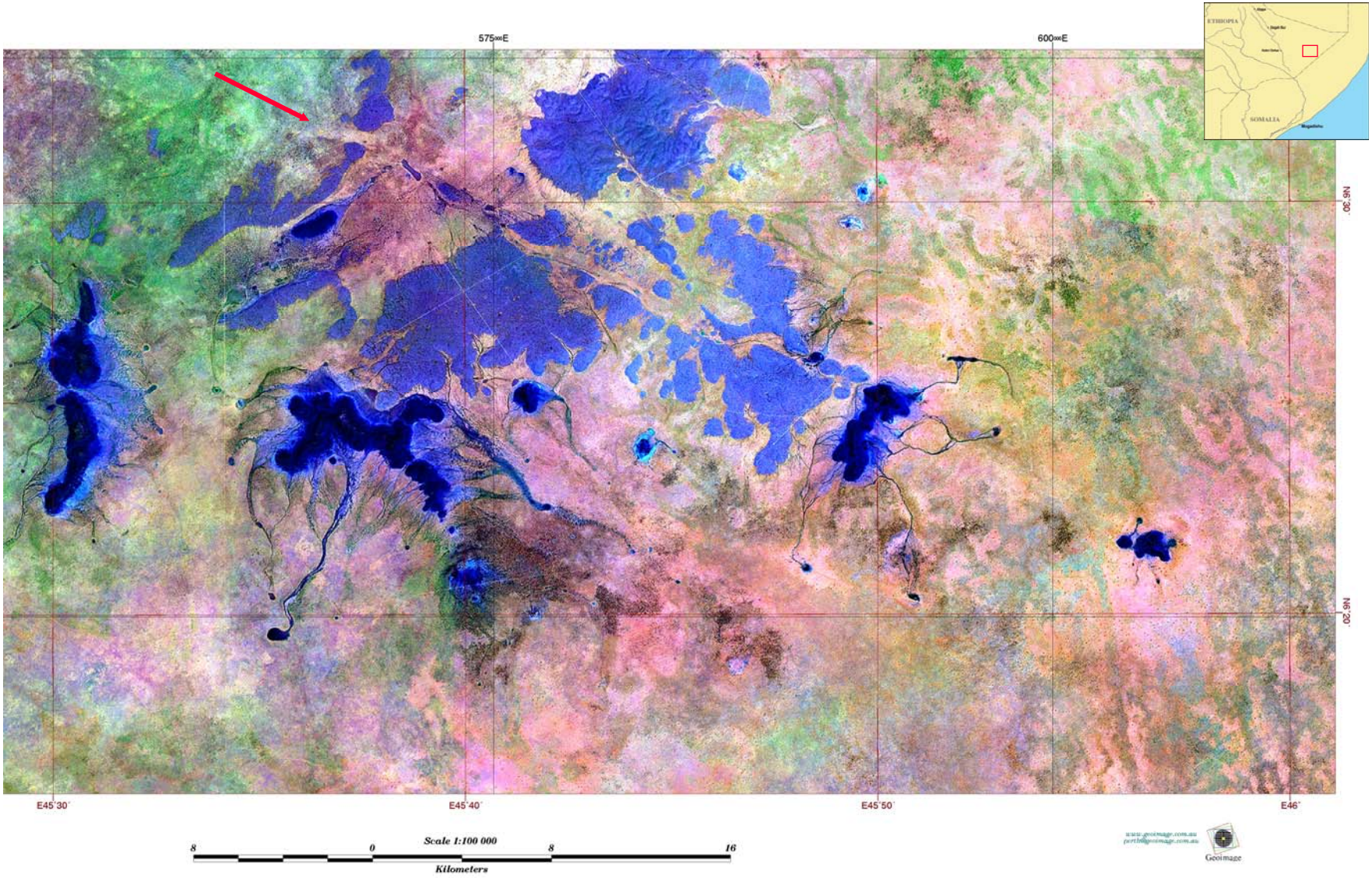

Ilbah Hills complex

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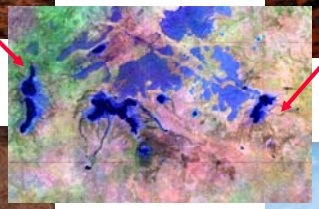

Ilbah Hills complex

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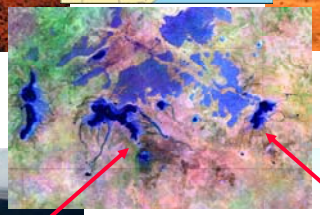

Aerial views, north along central Ilbah Hills

Dyke system, Raqo, Ilbah Hills

Gumburo-1 oil exploration well

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- Volcanic-related structures misled early oil explorers
- The first well by Sinclair Petroleum in 1949/50 was located on an uplift caused by surface and near surface volcanics.
- The surface volcanics have been identified as mugearite, formed from a lava transitional between basalt and trachyte.
- This volcanic hill, because of its commanding view of the surrounding region, has been a strategic military vantage point in recent decades in clashes between Ethiopian and Somalian forces.
- Note the recently renewed defensive trench on the hill top.

Marda volcanic lineament

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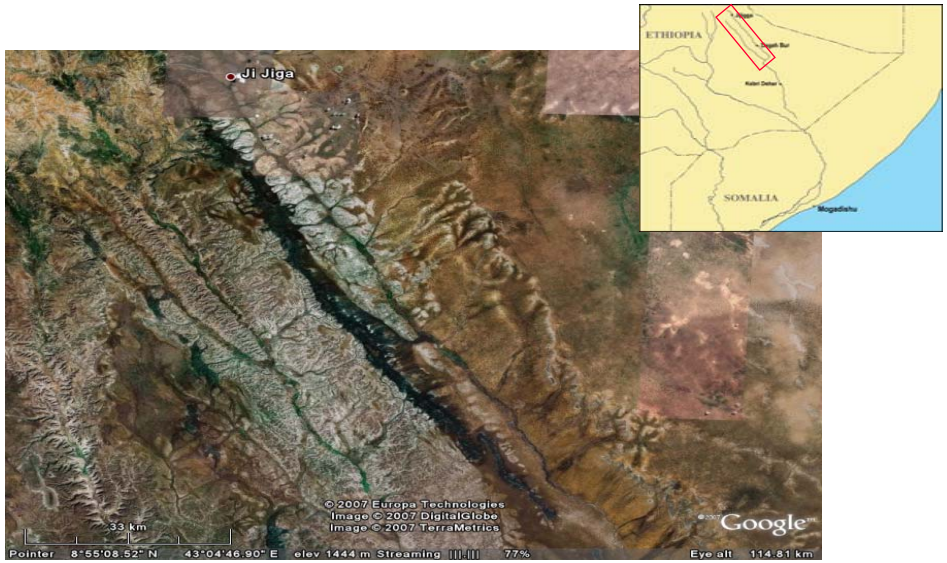

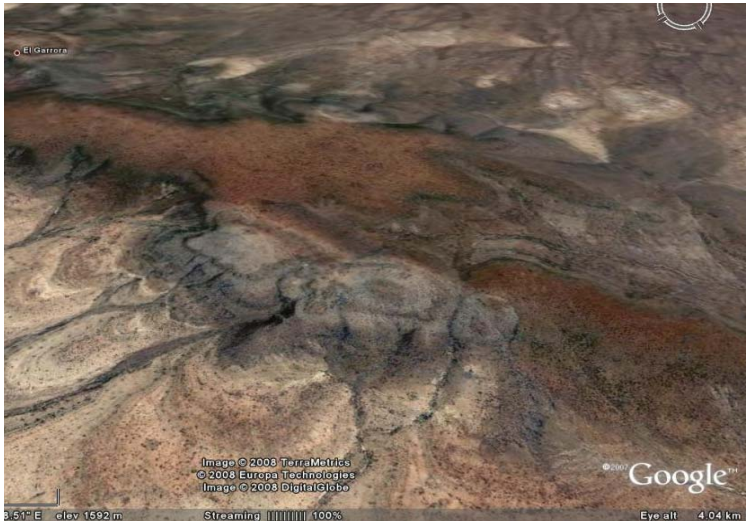

- **The best known volcanic outcrop in the region is the Marda 'volcano-tectonic line' first recognized in 1920 and prominent as a dark lineament on satellite imagery (upper left)**
- **The Marda Fault Zone is a Precambrian mylonite zone that has been reactivated several times during the Phanerozoic, including during the Oligocene volcano-tectonic event**
- **The range is marked by uplifted and eroded hills of Jurassic limestone, capped by the basalt layer,**

Impact on local demographics and culture

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- The Marda Range provides a natural boundary between the dominantly Oromo people to the west (above right) and the mainly Somali people to the east (above left), a change sharply marked in some seasons by the colour of the land.
- Jijigga, the capital and administrative centre of Ethiopia's Region 5, is located east of the ranges, near a prominent break in the ranges, known as the Marda Pass.
- The road through the pass connects Somaliland's capital Hargeisa through Jijigga to Harar and Addis Ababa.
- The Marda Pass was the site of major fighting during the defeat of the Italian army by British/Ethiopian forces in 1941

TMI 2VD map, Marda Fault Zone, Daghabur area

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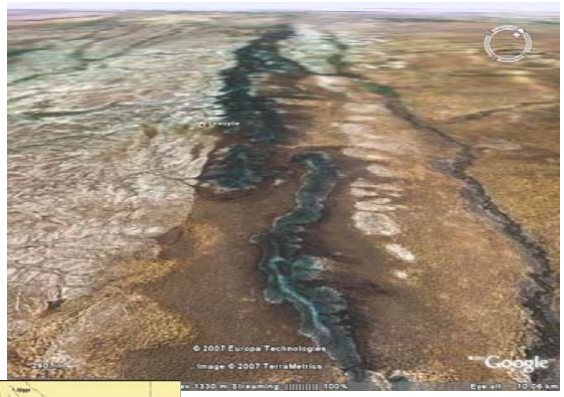

- **The linearity of the outcrop has been interpreted in terms of fissure eruption along the fault zone**
- **However, a meander-like form at the southern has prompted speculation that the linearity results from lava filling an ancestral Fafan River**
- **Magnetic data collected during oil exploration in the 1970s shows prominent NW/SE and NE/SW high frequency/amplitude anomalies that appear to be related to shallow dykes.**
- **Recently completed field work has confirmed a major basalt unit capping the ranges, as well as significant intrusive activity, revealing a complex multi-phase magmatic history**

Magnetic data, southern Somalia

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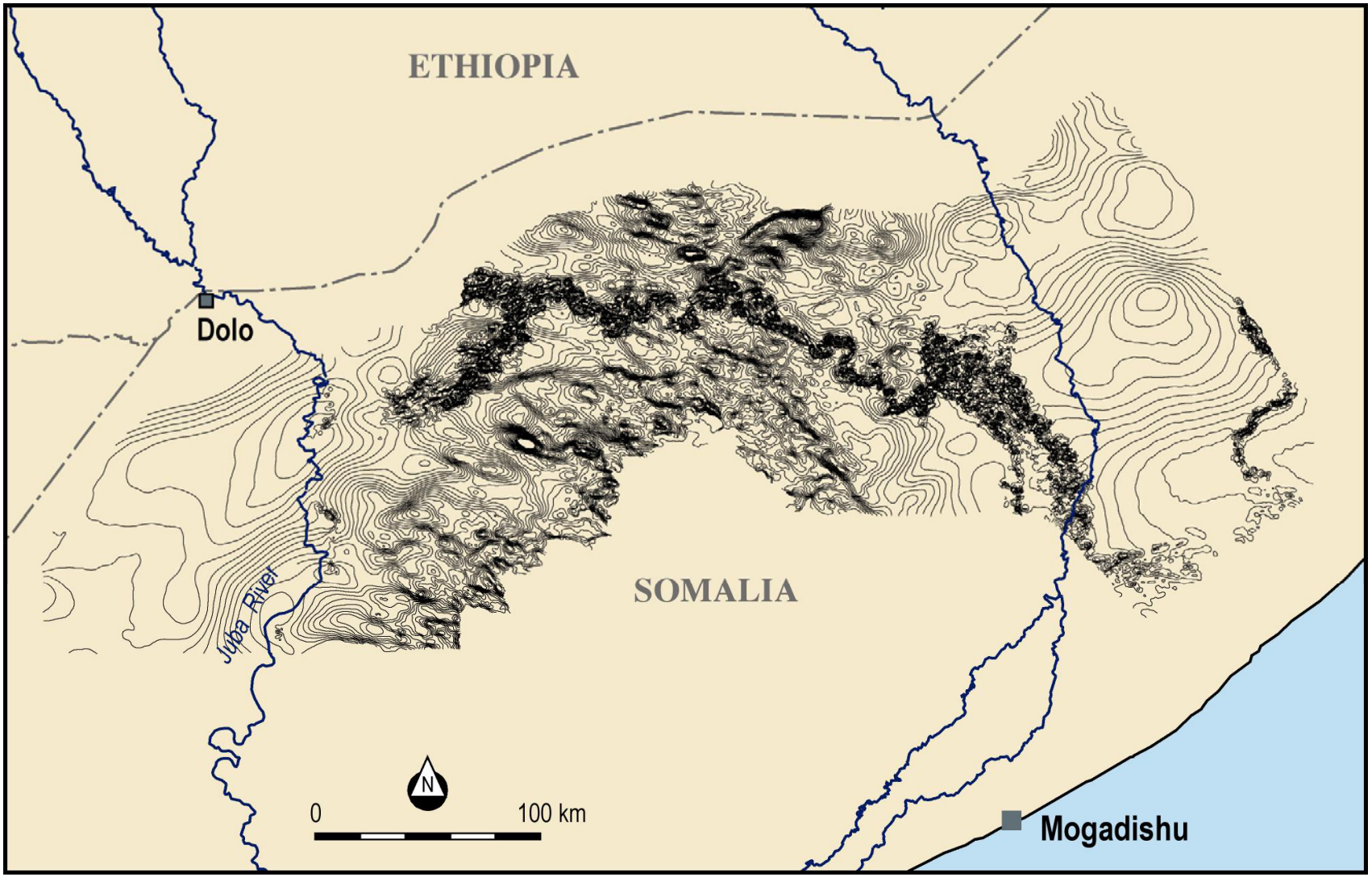

Magnetic data collected by Esso in 1984 shows a major belt of high amplitude, high frequency anomalies that extending 400 km across Somalia. A second band of high frequency anomalies is evident at far right. **The co-operation of Esso in releasing this data is gratefully acknowledged.**

Magnetic data, southern Somalia

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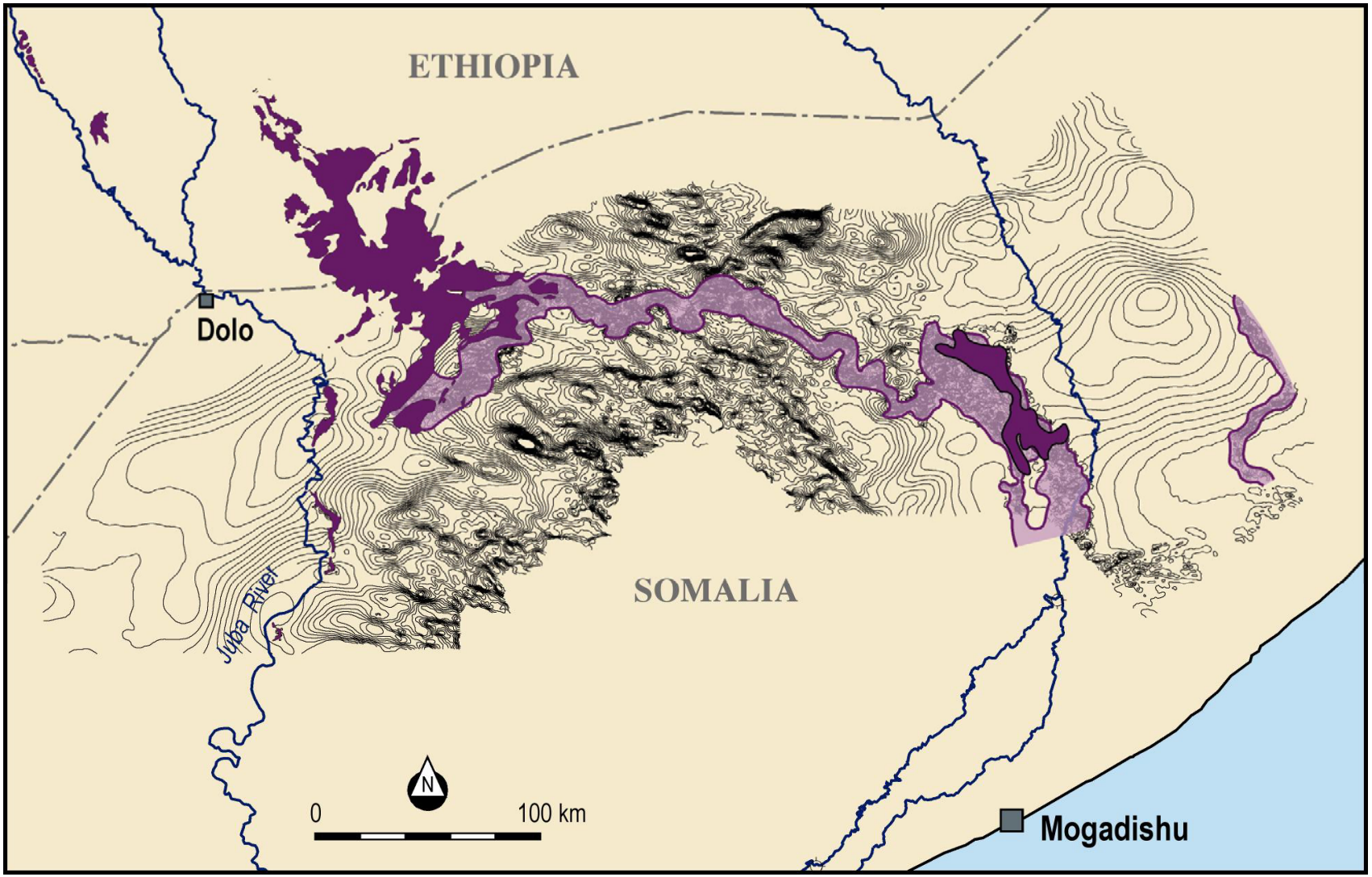

The magnetic data show continuity between the basalt outcrops east of Dolo and those along the Wabe Shebelle north of Mogadisho, suggesting lava flows filled a major river-valley system, with the central area now buried below thin alluvium in the modern Oddur Valley.

Basalt outcrops, SE Ethiopia/Somalia

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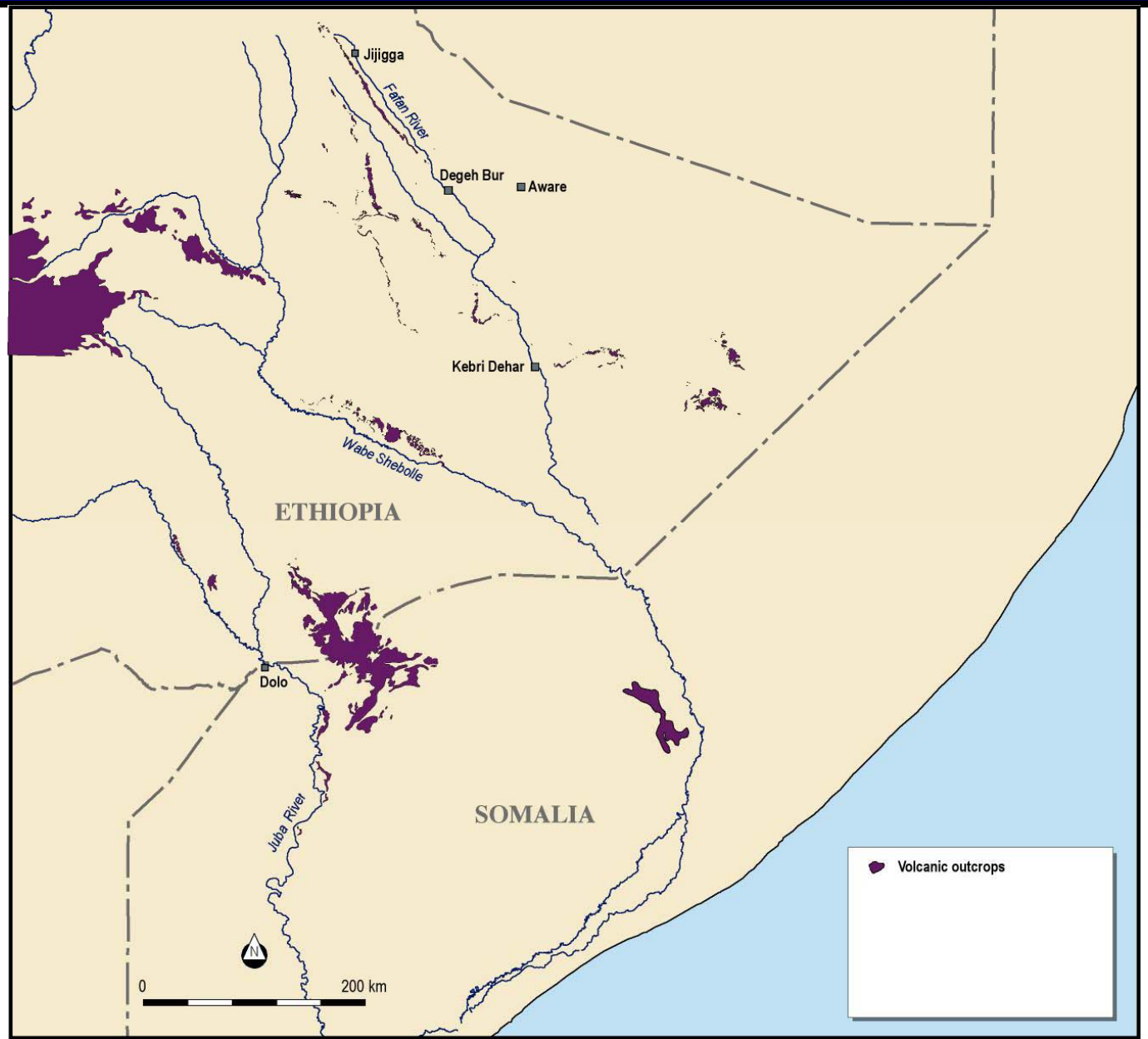

Basalt outcrops and magnetic indicators, SE Ethiopia/Somalia

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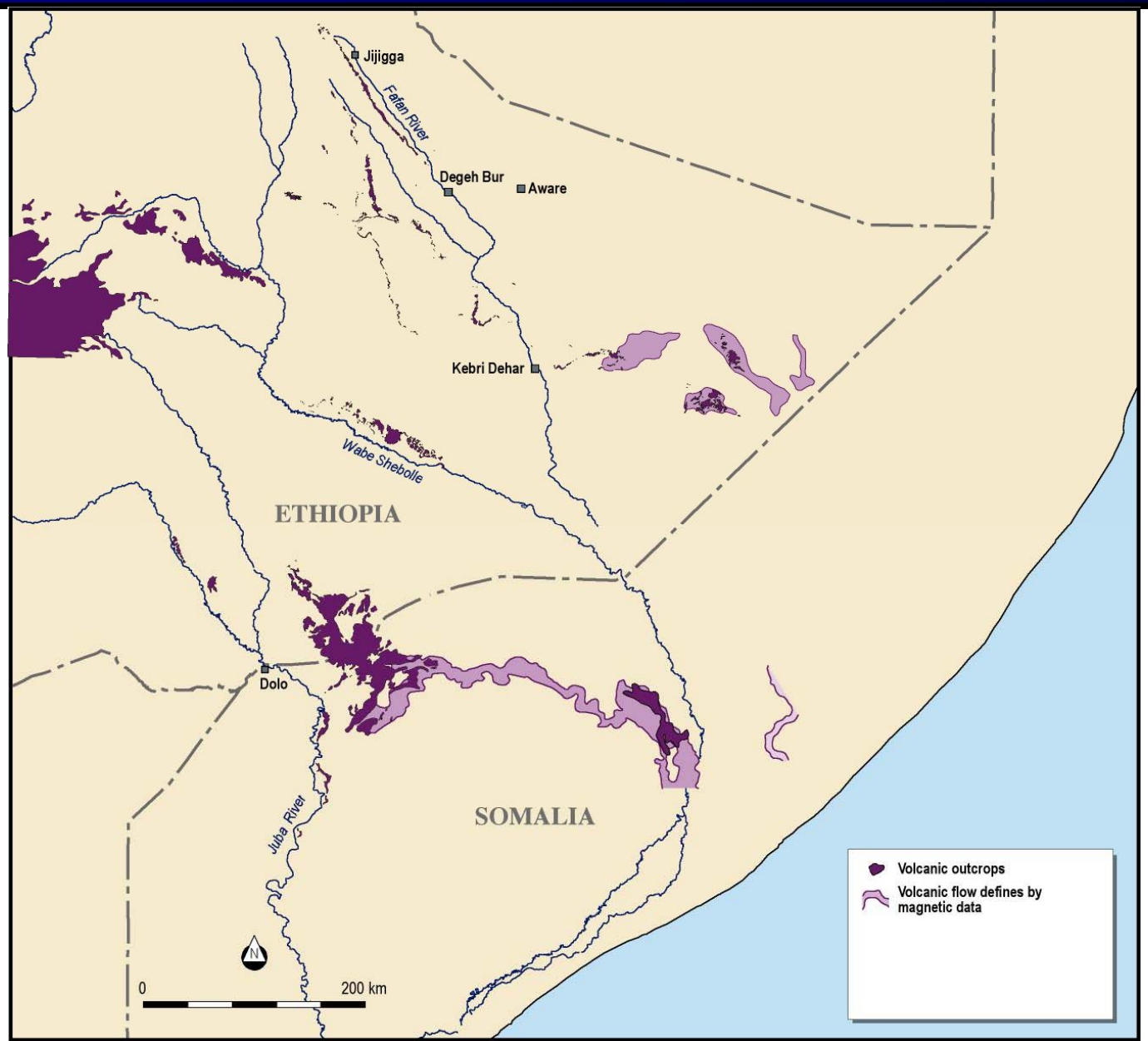

Basalt outcrops, magnetic indicators and well intersections, SE Ethiopia/Somalia

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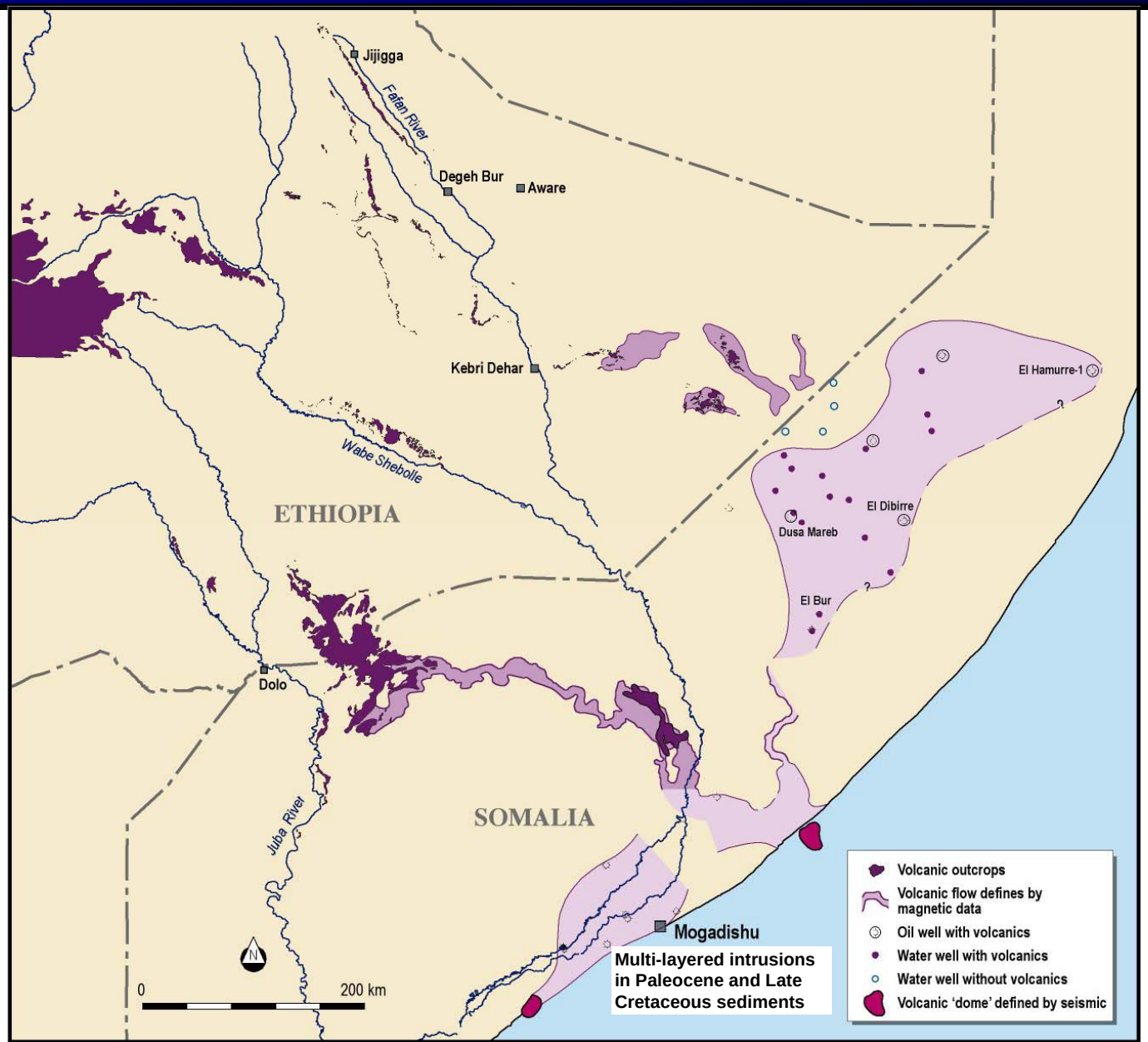

Age-dating of volcanics

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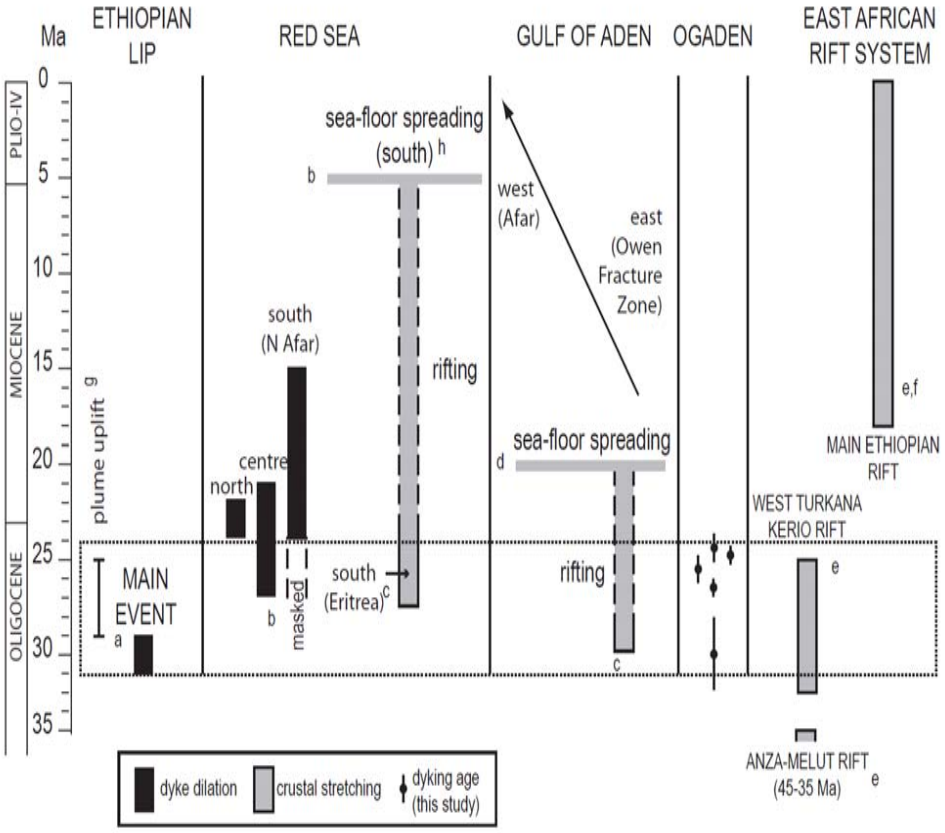

- **Samples from the Kebri Dehar, Ilbah and Marda volcanic complexes show a late Oligocene age of 24-27 My, with one sample slightly older at 30 My.**

- **The 24-27 My extrusions are coeval with the main dyke injection event in the southern Red Sea, and rifting in the Gulf of Aden and the parallel Darror and Nogal grabens onshore**

East-west cross-section, SE Ethiopia and Somalia

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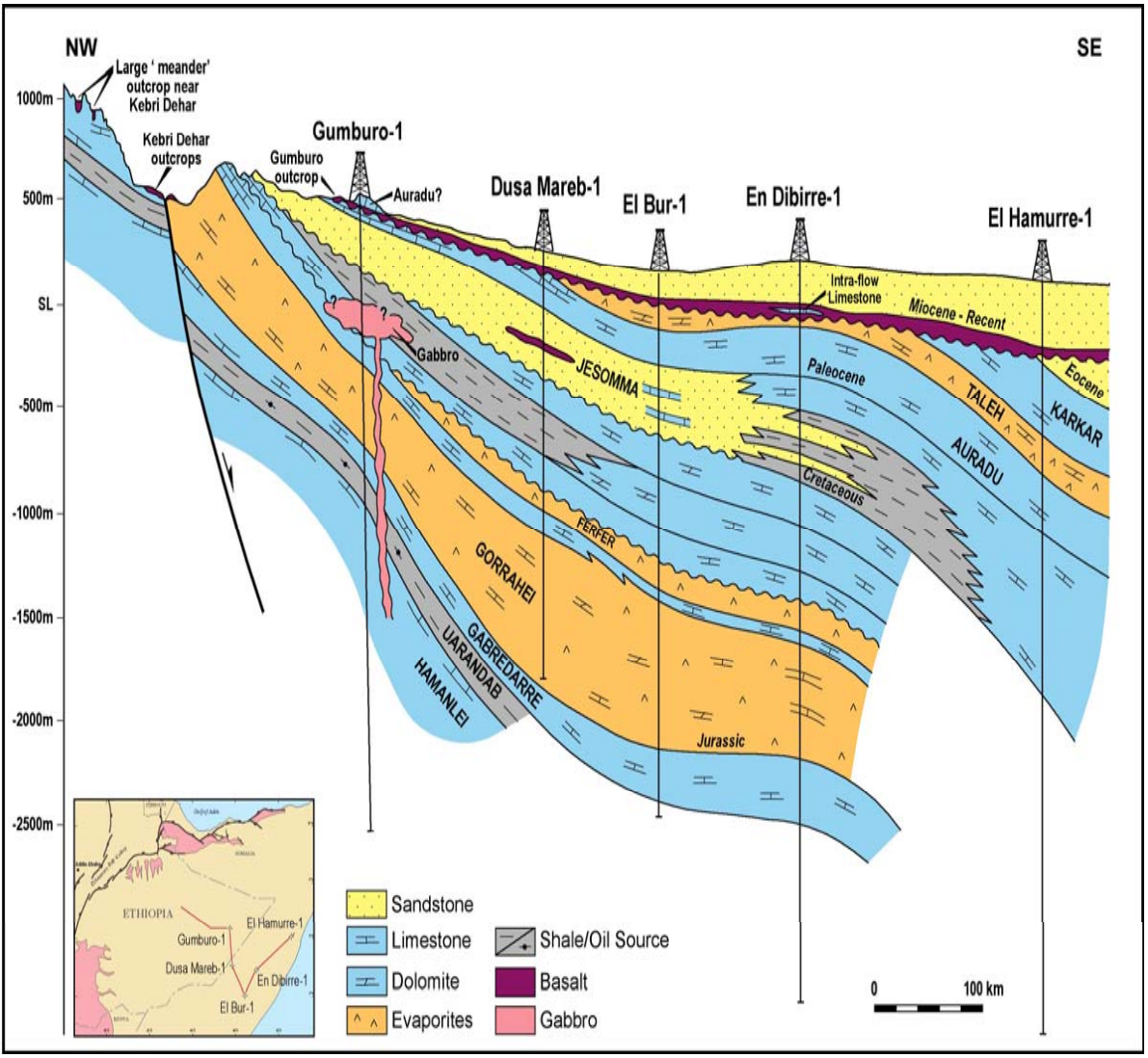

- The extensive basalt layer encountered in wells in eastern Ethiopia and central Somalia overlies a major unconformity separating Eocene and Miocene-Recent sediments, consistent with the Late Oligocene age of the basalts.
- Further west the basalt overlie Cretaceous and Jurassic sediments.
- The surface geology during the Late Oligocene uplift and erosion was not dissimilar to that prevailing today, and the basalts flowed over sediments of Jurassic to Late Eocene age.
- Well also reveal basalt extrusions within the continental Paleocene Jesomma sandstones and a gabbroic intrusion was encountered in Gumburo-1
- Wells to the southeast in coastal Somalia also show extensive intrusions within the Upper Cretaceous section, and belonging to a different tectono-magmatic event..

Late Oligocene paleogeography

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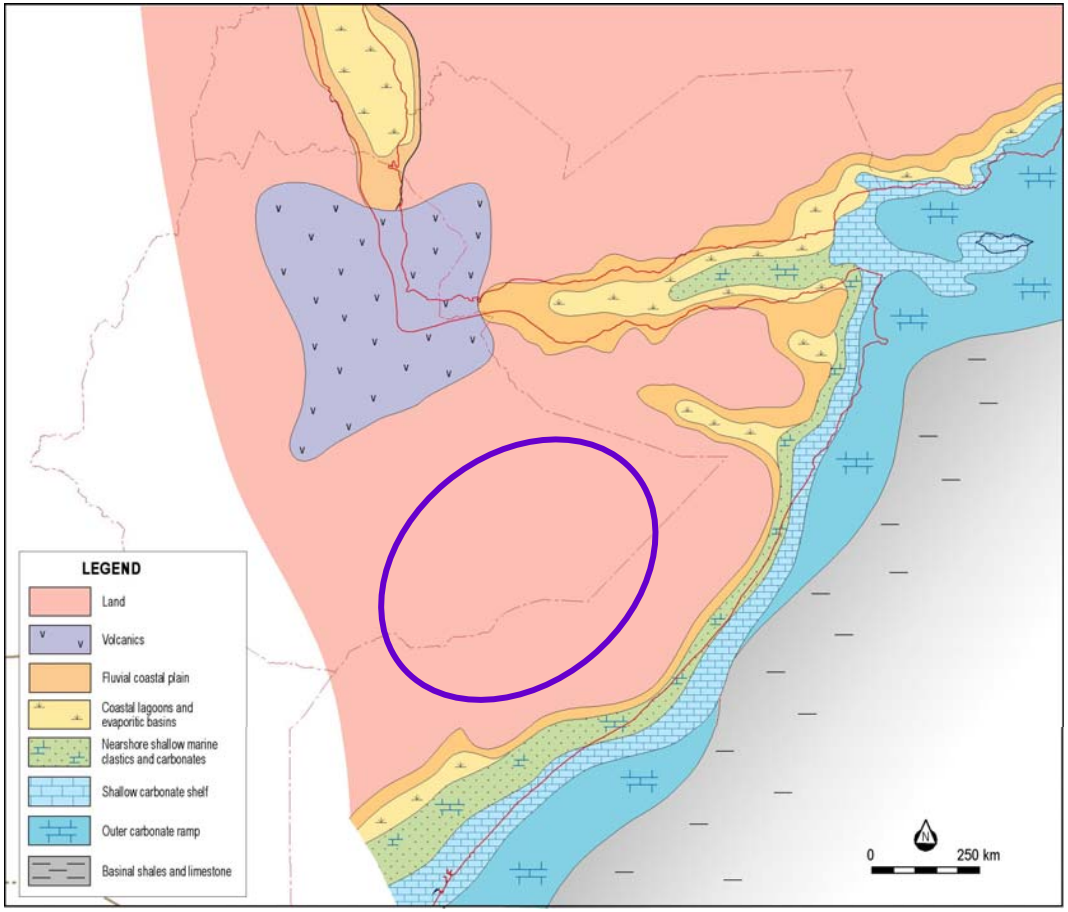

When lava fields began to spread across SE Ethiopia and Somalia in the Late Oligocene, much of the area probably resembled the Ogaden of today: vast flat, red with wind blown Paleocene sands

- By Late Oligocene the Horn of Africa coastline was similar to the present day, except for narrow re-entrants in the Nogal and Darror valleys
- The Gulf of Aden and Red Sea were shallow marine – lagoonal basins.
- Voluminous lava flows progressively filled the subsiding rift valley and poured out across northern Ethiopia and Yemen.

Summary and status of project

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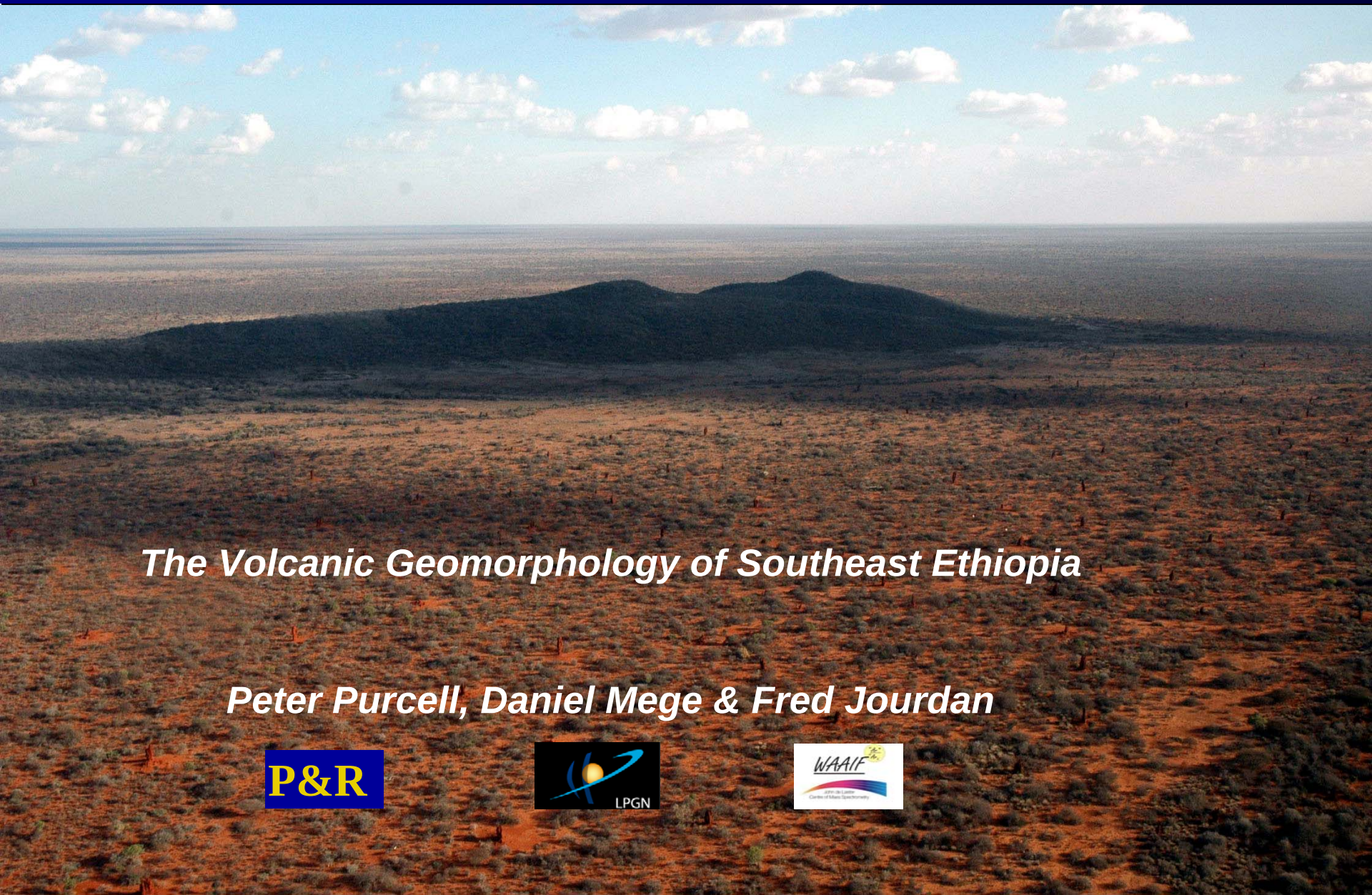
- Field mapping and sampling of northern Marda Fault Zone initiated
- New map of volcanics being prepared for publication, along with results of studies on samples collected in 2008
- Expand mapping of Marda Fault Zone and other features such as Daga Medo in coming field seasons, subject to security conditions
- Integrate this volcanism into the broader tectono-magmatic scheme of the Afro-Arabian rifting
- Expand magnetic data base by liaison with exploration companies and organize a new survey of Marda Fault Zone
- Use geomorphometry to determine paleo-tilting of topography, to indicate large-scale volcanic flow direction, and Ogaden uplift rate since the eruption



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