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# DYNAMIC EVOLUTION OF THE ZAMBEZI-LIMPOPO WATERSHED, CENTRAL ZIMBABWE

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## ABSTRACT

Prospecting carried out to the south of the Zambezi-Limpopo drainage divide in the vicinity of Bulawayo, Zimbabwe, led to the recovery of a suite of ilmenites with a chemical “fingerprint” that can be closely matched with the population found in the early Palaeozoic Colossus kimberlite, which is located to the north of the modern watershed. The ilmenite geochemistry eliminates other Zimbabwe Kimberlites as potential sources of these pathfinder minerals. Geophysical modelling has been used to ascribe the elevation of southern Africa to dynamic topography sustained by a mantle plume; however, the evolution of the modern divide between the Zambezi and Limpopo drainage basins is not readily explained in terms of this model. Rather, it can be interpreted to represent a late Palaeogene continental flexure, which formed in response to crustal shortening, linked to intra-plate transmission of stresses associated with an episode of spreading reorganization at the ocean ridges surrounding southern Africa. It is proposed that the formation of the flexure was a dynamic process, with the initial locus of flexure located to the north of the Colossus, resulting in the dispersal of ilmenites to the south of this kimberlite. Subsequently, the axis of flexure migrated to its present position, to the south of Colossus.

## INTRODUCTION

Plate tectonic concepts (Le Pichon, 1968) provide a unified framework for interpreting tectonic processes at plate boundaries. However, more than 40 years after the theory was tabled, there remains considerable debate surrounding the origins of vertical (epeirogenic) motions of continents. Plumes have been invoked as a driving force, with, for example, the anomalously elevated topography of southern Africa ascribed to dynamic uplift over a putative extant African plume (e.g. Lithgow-Beterlloni and Silver, 1998; Gurnis et al., 2000). However, this mechanism predicts domal uplift of southern Africa, and a radial drainage pattern, whereas the interior of this region is a topographic "low", associated with the Cenozoic Kalahari basin (Fig. 1). Further, instead of a radial drainage pattern, the major river divides in southern Africa define three roughly concentric arcs, broadly parallel to the coastline (Moore, 1999; Moore et al., 2009a) (Fig. 1).

These unusual aspects of southern Africa topography are not readily interpreted in terms of dynamic (plume-sustained) uplift. An additional complexity is that the three watersheds are of different ages (Moore, 1999; Moore et al., 2009) – which is also not predicted by dynamic uplift over a plume. The oldest is the outer divide (the Escarpment Axis), initiated in the Early Cretaceous, coeval with the disruption of Gondwana. The central divide (the Etosha-Griqualand-Transvaal or EGT Axis) is mid-Cretaceous in age, and broadly coeval with a major episode of reorganization of plate spreading in the Atlantic and Indian Oceans. The inner drainage divide (the Ovambo-Kalahari-Zimbabwe or OKZ Axis) was initiated in the late Palaeogene, broadly coeval with a reorganization of spreading of the Indian Ocean Ridge, and a marked increase in spreading rate at the mid-Atlantic Ridge (Moore et al., 2009a).

The river divides were interpreted to reflect axes of epeirogenic uplift by Maufe (1927, 1935). This interpretation was endorsed by du Toit (1933), who also stressed that subsidence of the Kalahari Basin accompanied uplift along the EGT and OKZ Axes. Moore et al. (2009a) noted that the coincidence in timing of uplift of each of the axes with volcanic activity in southern Africa, as well as episodes of reorganization of the oceanic spreading ridges surrounding southern Africa, pointed to a casual link with plate margin processes. They suggested that vertical motions on the continent reflected lateral transmission of stresses across the African Plate, associated with changes in the plate spreading regime at the ridges. A more refined appreciation of the nature of these vertical (epeirogenic) continental motions would allow a clearer understanding of their relationship to plate margin driving forces.

The aim of this study is to present results from a kimberlite prospecting programme in Exclusive Prospecting Orders (EPOs) in the Bulawayo area of western Zimbabwe (Fig. 2), and their bearing on the development of the OKZ Axis, which today forms the watershed between the major Limpopo and Zambezi drainage basins (Fig. 1). These EPOs, referred to in-house as the Bulawayo Block, were investigated in the mid-late 1990's by Somabula Explorations (Pty) Ltd. – a private Zimbabwe-registered diamond exploration company, managed by the first author. The northern extremity of the Bulawayo EPO block straddles the central Zimbabwe watershed (Figs. 2 & 3).

**GEOLOGIC SETTING OF THE BULAWAYO EPO's**

The regional geological setting of the EPOs investigated by Somabula Explorations, is illustrated in Figs. 2. The entire block is underlain by the granite-greenstone complex of the Archaean Zimbabwe Craton. To the north, the Archaean basement is overlain with a marked unconformity by Permian to Triassic Karoo sediments, capped by an early Jurassic basalt. The Karoo sequence is in turn unconformably overlain by unconsolidated and semi-consolidated sands of the Kalahari Group. The Karoo and Kalahari sequences both thicken to the northwest. To the northeast of the Bulawayo block, there is a linear outcrop of Karoo sediments, in part overlain by Kalahari cover, with an impersistent basal diamond bearing gravel (the Somabula Gravels).

A group of kimberlites, discovered in the early 1900's, are located just to the north of the central Zimbabwe watershed. The largest of these is Colossus (Fig 2), with a reported grade of 2.76ct/100t, and a diameter of ~900m, , although this may prove to be a composite body, comprising two separate pipes (Mafara, 2000). Two small non-diamondiferous bodies (Prospects S1 and S2, not shown in Fig. 2) are located within 2 km of Colossus. The Wessels Sill, located some 10 km to the east of Colossus is also poorly diamondiferous (~1.4ct/100t). Moffat and Clare to the northeast are both small pipes that are either low grade or barren (Fig. 2) (Mafara, 2000). Colossus has been dated at 533 +/- 7 Ma (Phillips, 1999), and it is probable that the associated kimberlites are also Lower Palaeozoic in age.

Subsequent exploration work in Zimbabwe resulted in the discovery of a number of post-Karoo kimberlite clusters in the Zambezi Valley (Fig. 4). These all proved to be either barren or to contain only trace amounts of diamonds (Mafara, 2000). Several groups of kimberlites were also discovered to the south of the central Zimbabwe watershed (Fig. 4) (Mafara, 2000), including the economic River Ranch and Murowa pipes. The former is described as "low grade" (Muusha, 1997), while the latter has a reported grade of 90ct/100t (Rio Tinto Zimbabwe Ltd., 2004). The Mwenezi-1 kimberlite in the southeast of Zimbabwe has a sub-economic grade of <10ct/100t (Williamson and Robey, 1999). The Ngulube kimberlite in southeast Zimbabwe is diamondiferous but low-grade, while the Mambali kimberlite, from the same cluster, produced one small (0.5ct) diamond from 1553 tonnes of surface material processed (Mafara, 2000). The remaining kimberlites south of the watershed are believed to be either low-grade or barren.

The Mwenezi kimberlites have been dated at ~ 520 Ma (Phillips et al., 1997), while ages of 430 +/- 6 Ma and 740 +260/-310 Ma have been reported for the River Ranch pipe (Kramers and Smith, 1983). Dolerite dykes of presumed Karoo age cut the Mwenezi-1 kimberlite (Williamson and Robey, 1999), and also the Ngulube pipe (Martin Spence, personal communication, 2002). The Juliasdale kimberlite has been metamorphosed (Mafara, 2000), suggesting that it pre-dates the Pan African orogeny. Collectively, this evidence suggests that most of the kimberlites south of the watershed are pre-Karoo, and likely early Palaeozoic in age, with the Juliasdale pipe being even older.

## GEOMORPHIC SETTING OF THE BULAWAYO EPOs

Amm (1937) used borehole evidence to reconstruct the pre-Karoo surface beneath the Karoo sedimentary basin to the north of the watershed. His study showed that this surface is characterized by a low relief, and a regional slope to the northwest. Moore et al. (2009b) noted that south-east oriented "fingers" at the southern extreme of the Karoo outcrop (Fig. 2) filled pre-Karoo valleys, and thus reflected an inverted topography. The elongate Somabula Karoo outcrop to the northeast (Fig. 2), which also fills a pre-Karoo valley, is a further example of such inverted topography.

Moore et al. (2009b) pointed out that the upper reaches of modern tributaries of the Zambezi River, to the north of the watershed, have a general northwest orientation broadly parallel to the pre-Karoo drainage lines. They noted that this pattern is not in accord with the present-day east-flowing Zambezi River, indicating that the extant drainage system to the north of the watershed is controlled by a regional slope that has been inherited from pre-Karoo times. Moore et al. (2009b) presented evidence that the modern watershed was originally mantled by Karoo sediments. Stripping of this cover exhumed the pre-Kalahari floor.

Lister (1987) presented evidence for pre-Karoo palaeo-surfaces south of the modern watershed (e.g the summit of Wedza Mountain), and inferred that the pre-Karoo watershed would have been located some 150-200 km to the south of the modern watershed (Fig. 4, 1600m contour). Moore et al. (2009b) also envisaged that the pre-Karoo watershed was located to the south of the modern divide, but proposed that alluvial diamonds in the basal Karoo Somabula Gravels were ultimately derived from the Murowa-Sese kimberlites. This requires that the pre-Karoo river divide was located even further to the south than suggested by Lister (1987) (Fig. 4, heavy dashed lines). Moore et al. (2009b) argued that staurolite and kyanite, which dominate the heavy mineral suite in the Somabula Gravels, were derived from sources in the Nyanga and Chimanimani areas of the eastern highlands of Zimbabwe. This area must therefore have formed part of the headwaters of the Somabula drainage system, requiring that the watershed curved to the north following this elevated terrain (Fig. 4).

The modern central Zimbabwe watershed is characterized by a gently undulating topography (Fig. 5), which Lister (1987) ascribed to the African erosion cycle. Moore and Moore (2006) however noted that deep weathering profiles characteristic of the African Surface (Partridge and Maud, 1987) are rare on the watershed. They argued that the African surface weathering carapace developed on the former Karoo cover over the modern watershed, and that the modern senile, low relief divide is an exhumed pre-Karoo surface, exposed by stripping of this cover. Lister (1987) questioned the view that the watershed represented an axis of flexure, as originally proposed by Maufe (1927, 1935) and du Toit (1933). She suggested rather that it represented the present locus of headward erosion to the north, reflecting that the steeper gradient south-draining river system was more aggressive than the lower gradient system to the north of the watershed. However, Moore (1999) subsequently presented evidence that supported the original Maufe-du Toit interpretation that this divide represents an axis of flexure.

## PROSPECTING IN THE BULAWAYO EPOs

Somabula Explorations carried out a reconnaissance drainage sampling programme over the entire EPO block, at a density of 1 sample/20 km$^2$. This resulted in the recovery of a diffuse scatter of kimberlitic picroilmenites (with diameters > 0.5mm) in the headwaters of the south-draining river system, in the extreme north of the EPO block (Figs. 2 & 3). Several phases of detailed follow-up sampling were carried out in the vicinity of the initial anomalous sample sites. While further picroilmenites were recovered, the follow-up work failed to define any bulls-eye concentrations of these kimberlitic pathfinder minerals, arguing against a proximal source. Subsequent prospecting in this area by other companies also failed to locate a local kimberlite source. These results suggest that the diffuse scatter of kimberlitic ilmenites recovered in the north of the Bulawayo Block represents a secondary pathfinder anomaly, derived from a distal source. Clearly, from the perspective of kimberlite prospecting, it is important to identify where this source is located.

## ILMENITE FINGERPRINTING

There are frequently significant differences in the chemical fields defined by suites ilmenites from different kimberlite pipe clusters. This is illustrated in Fig. 6, where the compositional field for the Bulawayo Block ilmenites is compared with those for a number of different kimberlite clusters in central and southern Zimbabwe. More subtle differences in ilmenite compositional fields often characterize different kimberlites within the same pipe cluster (Mitchell, 1973; Lee, 1993; Moore and Lock, 2001). This is illustrated for three kimberlites (Colossus, Wessels and Moffat) from the Colossus cluster (Fig. 7a). Ilmenite compositional fields (rather than individual ilmenite compositions) thus provide a “chemical fingerprint” of the host kimberlite, which is invaluable during prospecting operations. The recovery of a suite of ilmenites with a chemical fingerprint which cannot be matched with those from known kimberlites provides compelling evidence for the existence of an undiscovered source.

Given the evidence that the pre-Karoo watershed was located to the south of the modern divide, it is possible that the ilmenites recovered within the Bulawayo Block could have had a provenance to the south. The data presented in Fig. 6 shows that the chemical fingerprints for the Mwenezi, Mungezi and Charter kimberlites bear no resemblance to that for the Bulawayo Block suite. The former three localities can therefore be ruled out as potential sources of the unexplained anomaly identified by Somabula Explorations. The same applies to the Ngulube kimberlite, which lacks picro-ilmenite (Martin Spence, personal communication, 2002). Data for ilmenites from the Murowa-Sese area (Fig. 4), kindly made available by Rio Tinto plc, shows that a significant proportion of the ilmenites in this area are markedly enriched in Mn. This distinguishes these ilmenites from those in the Bulawayo block, which are Mn-poor. The closest match to the latter suite is provided by the Colossus-Moffat pipes, to the north of the watershed, and the Mambali kimberlite (Fig. 6), which is located in the Ngulube cluster in the southwest of Zimbabwe (Fig. 4).

Fig. 7a shows that virtually all of the Bulawayo ilmenites fall within the compositional field defined by the Colossus kimberlite cluster. The particularly close correlation with the ilmenite field for Colossus flags this kimberlite as a potential primary source for the ilmenite anomaly in the north of the Bulawayo block. Fig. 7b provides a more detailed comparison between the Bulawayo ilmenite suite and those from the Mambali kimberlite. There is a relatively poor correlation between their respective fields, which argues that the Mambali kimberlite is unlikely to be the source of the pathfinder anomaly identified in the north of the Bulawayo Block. This conclusion is consistent with Lister's reconstruction of the pre-Karoo surface to the south of the modern watershed. The surface was inclined to the northwest, and Karoo-age glacial or fluvial systems would therefore be expected to have dispersed pathfinder minerals well to the west of the Bulawayo Block. The northwest drainage direction is also consistent with the suggestion by Moore et al. (2009b) that a major pyrope garnet-diamond pathfinder anomaly associated with the Kalahari margin at

Maitengwe (Fig. 2) might be derived from a source in the Ngulube area. The lack of ilmenite in this anomaly would reflect the relatively higher density of this phase (~4.5) relative to pyrope garnet and diamond (~3.5). The higher density ilmenite tends to concentrate as a lag, proximal to the source, leading to an increase in the ratio of garnet (+/-diamond) relative to ilmenite during dispersion away from the source kimberlite (Grey, 1976). Quantitative evidence for this separation of kimberlitic ilmenites and garnets during transport is presented in the following section.

In summary, a comparison between the field of the unexplained Bulawayo Block ilmenites with those for other kimberlites in Zimbabwe indicates a close match with the Colossus ilmenite suite. This suggests that the latter kimberlite is the ultimate source of the Bulawayo anomaly, but such an origin begs explanation of how heavy minerals were dispersed over a distance of 40-50 km to the south of the modern watershed from a source located to the north of the divide (Fig. 3). This is considered in the following section.

**DISPERSION OF KIMBERLITIC MINERALS FROM SOURCE ROCKS**

Kimberlitic Searches Ltd., the Zimbabwe subsidiary of de Beers Consolidated Mines, discovered two small kimberlites on the low-relief central Zimbabwe watershed in the Charter area of Zimbabwe (Fig. 4) during the tenure of EPO 466 (Kimberlitic Searches, 1975). The loam sampling programme which led to their discovery outlined an anomalous ilmenite concentration (in the approximate size range 330-1500µm) in close proximity to the two kimberlites. However, the numbers of ilmenites recovered showed a marked decrease away from source, with a majority of samples being barren beyond a distance of 2-3km. These results illustrate that processes such as soil creep and biological activity associated with, for example, ants, termites and moles, will disperse ilmenites over a very limited distance on low relief terrains such as the central Zimbabwe watershed. This argues strongly that mass soil movements and biological agents do not provide a satisfactory mechanism to account for the translocation of ilmenites from the Colossus kimberlite across the watershed into the Bulawayo EPO block.

In contrast, rivers are capable of transporting kimberlitic minerals over considerably greater distances. This is illustrated by the study carried out by Edwards (1958) in the Bembezi River, which directly drains the Colossus kimberlite via a minor tributary. Significant numbers of ilmenites in the 1-2 mm size fraction were recovered within 23.8 km of the pipe from sample volumes ranging between 1.3-4.6 cu. yd. Thereafter, recoveries diminished rapidly with no grains recovered after 33.65 km, or from a larger (5 cu. yd.) sample taken 40.1 km downstream of Colossus. However, the sampling programme recovered significant numbers of kimberlitic pyrope 138 km downstream of the pipe – the limit of the study. This pattern is a good illustration of the progressive increase in the garnet/ilmenite ratio associated with progressive fluvial dispersion away from the primary kimberlite source.

Garnets and ilmenites in smaller size fractions (0.5 – 1.0 mm) would be expected to be dispersed over greater distances than the respective coarse fractions of these two minerals from the Bembezi River that were examined by Edwards (1958). This is supported by qualitative data from sampling carried out by de Beers around the Orapa kimberlite field in Botswana (Grey, 1976). These data indicate that significant numbers of kimberlitic ilmenites in the >0.5mm size fraction were recovered up to at least 50 km down the original palaeo-slope from the nearest known kimberlite. It should be noted in passing that glaciers are capable of dispersing kimberlitic minerals over extensive distances (several 100km) (Craigie, 1993).

## TECTONIC IMPLICATIONS

The quantitative and qualitative results from the various kimberlite pathfinder sampling programmes indicate that mass soil movements and biological agents are unlikely to provide a satisfactory explanation for dispersion of ilmenites from Colossus over a distance of 40-50 km into the north of the Bulawayo block. Fluvial (or glacial) dispersion would appear to be the only satisfactory agents capable of transporting coarse (>0.5mm) kimberlitic minerals over such distances. Both processes would require former headwaters located to the north of the Colossus kimberlite, and thus to the north of the modern drainage divide.

The present drainage system to the north of the modern central Zimbabwe watershed has been interpreted to be inherited from a northwest oriented palaeo-slope, extant since Karoo times, with original headwaters well to the south of the modern divide (Lister, 1987; Moore et al., 2009b). This surface was ultimately disrupted by uplift along the OKZ Axis in the late Palaeogene (Maufe, 1927 & 1935; du Toit, 1933; Moore 1999; Moore et al., 2009b). This reversed the drainage network to the south of the flexure, but did not radically alter the system to the north.

Uplift along the line of the modern central Zimbabwe drainage divide would not account for dispersion of kimberlitic minerals from Colossus to the south into the area covered by the Bulawayo Block. To account for this dispersion pattern requires that the original line of uplift was located to the north the Colossus kimberlite, and thus to the north of the modern divide (Fig. 2). Following this initial uplift, rivers rising off the divide would have dispersed kimberlitic minerals from Colossus to the south. Subsequent to this initial uplift, the locus of the watershed migrated progressively southwards to its present position.

This interpretation supports the original views of Maufe (1927 & 1935) and du Toit (1933) that the modern watershed is a line of flexure. The alternative view (Lister, 1987) is that the divide migrated northwards from an initial position to the south of the modern watershed(Fig. 5) to the present position by simple headward erosion., However, this model would not explain the recovery of ilmenites from Colossus (to the north of the modern watershed) in the Bulawayo EPO block (located to the south of the watershed).

The evidence presented for evolution of the modern watershed as a result of the migration of an axis of flexure from north to south, raises the question of the mechanisms involved. It is not entirely possible to rule out some variant of the plume model to account for such a rolling flexure. Burov and Guillou-Frottier (2005) suggest that a non-Newtonian plume and a multi-layer brittle-elastic-ductile lithosphere could lead to a complex pattern involving both uplift and subsidence on various scales. Brown (2011) proposed that such processes provide a potential explanation for the flexure axes illustrated in Fig. 2, and that the model could be extended to explain a rolling flexure.

Nevertheless, this theoretical geophysical model is based on variables that are not readily constrained, and assumes a uniform lithospheric thickness. This contrasts with evidence for a marked thickening beneath the Archaean Kaapvaal and Zimbabwe cratons that form the nuclei to southern Africa (Fouche et al., 2004). Moreover, it is difficult to reconcile with the evidence that the three epeirogenic flexures are of different ages, and coeval with episodes of alkaline volcanic activity, as well as periods of reorganization of the spreading regime at the oceanic ridges surrounding southern Africa (Moore et al., 2008; 2009a). This problem is magnified by the fact that the volcanic episodes recognized in southern Africa are widespread across Africa (Bailey, 1993). Further, the ages of the southern African flexures correlates well with major unconformities in the Congo Basin (Cahen and Lepersonne, 1952; Giresse, 2005), pointing to linked tectonic processes across broad areas of Africa (Moore et al., 2009a). It is very difficult to account for all of these coincidences in terms of standard plume models.

Moore et al. (2009a) present evidence for a close temporal link between the ages of flexure axes in southern Africa and episodes of reorganization of the surrounding oceanic spreading ridges. They suggested that uplift along the inland flexure axes reflects continental shortening in response to intra-plate transmission of stresses linked to these spreading reorganizations. The rolling uplift might then be a reflection of changes in the geometry and magnitude of stresses along different sections of the ocean ridges.

A complementary, or possibly alternative driving force may be erosion and the coupled epeirogenic rebound triggered by continental flexing. Drainages flowing to the north of the Zambezi-Limpopo watershed are characterized by very gentle gradients (1:704), inherited from the pre-Karoo surface. In contrast, south-draining rivers are characterized by far steeper gradients (1:176) (Maufe, 1935). More aggressive erosion by rivers flowing south off the watershed would initiate a coupled isostatic rebound, which might either contribute to, or play the major role in a southerly migration of the watershed following the initial flexure.

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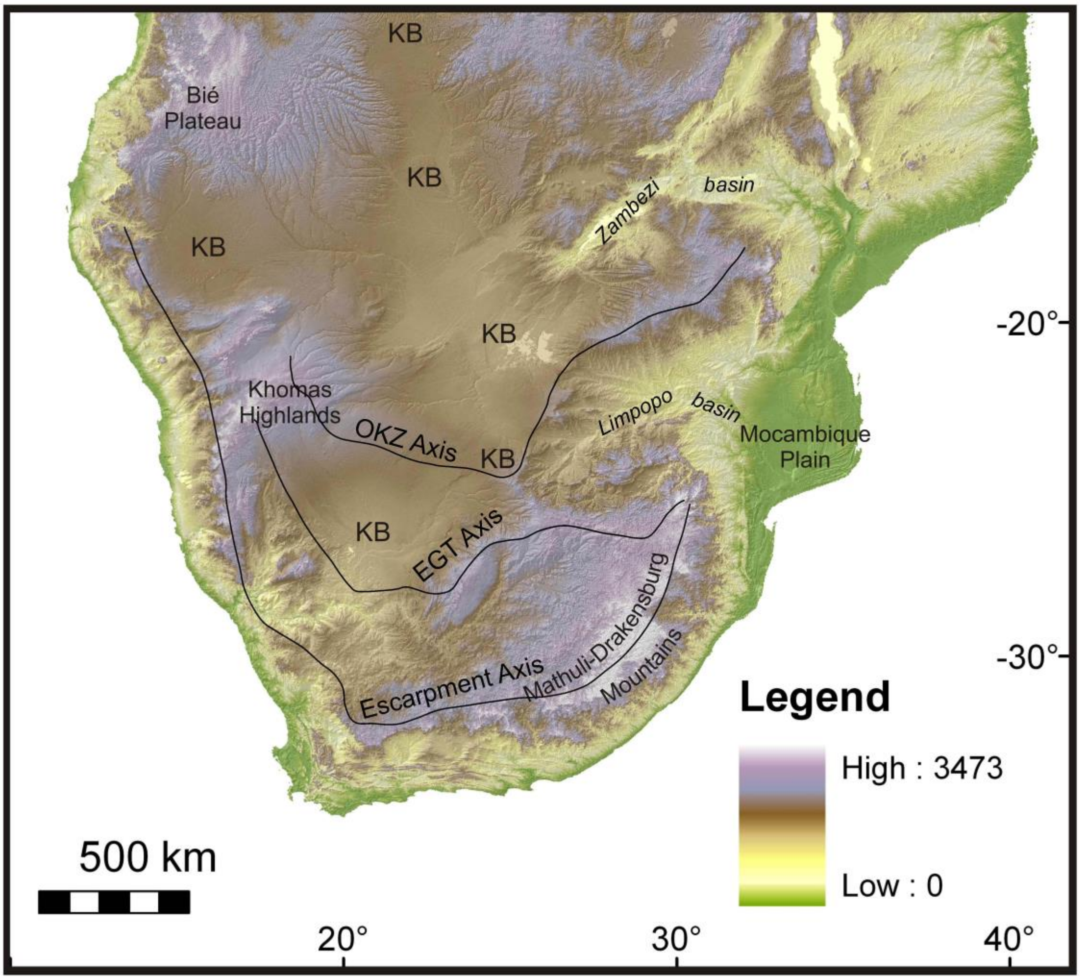


Fig. 1. SRTM digital elevation image for southern Africa. The highest elevations are associated with the marginal escarpment and the central Zimbabwe watershed. This high ground surrounds the Cenozoic sediments in the Kalahari Basin (KB). EGT = Etosha-Griqualand-Transvaal Axis; OKZ = Ovambo-Kalahari-Zimbabwe Axis. Elevations in metres.

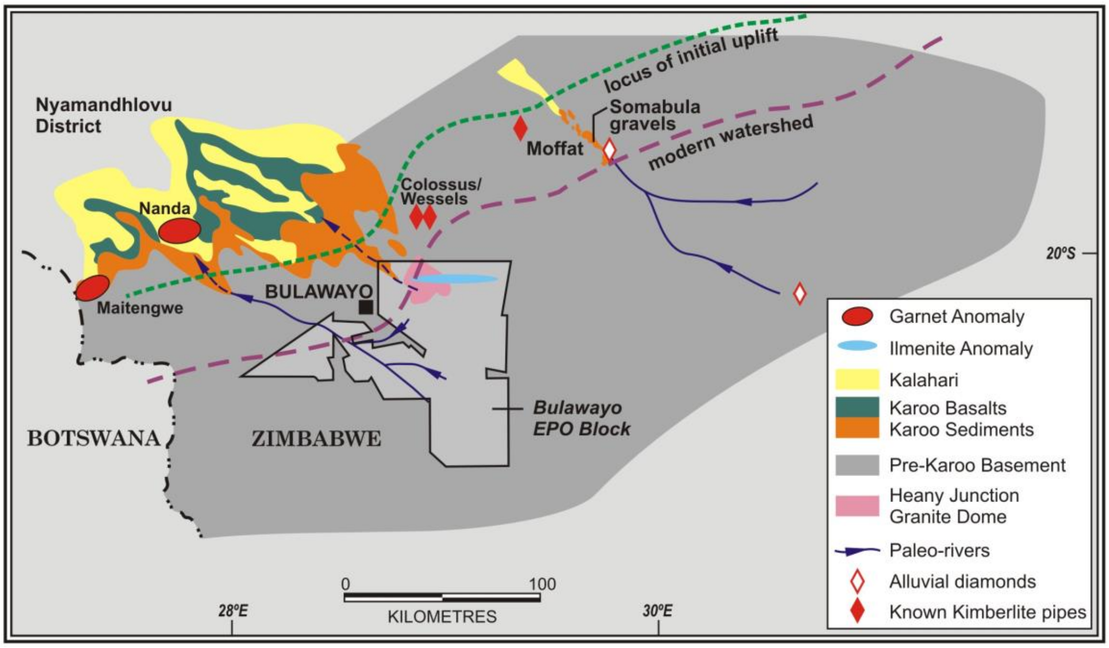


Fig. 2 Location of the Bulawayo EPOs in relationship to a simplified regional geology and the modern watershed (long-dashed lines) between the Zambezi and Limpopo drainage basins. Short-dashed line shows inferred initial locus of epeirogenic flexure, located to the north of the modern watershed

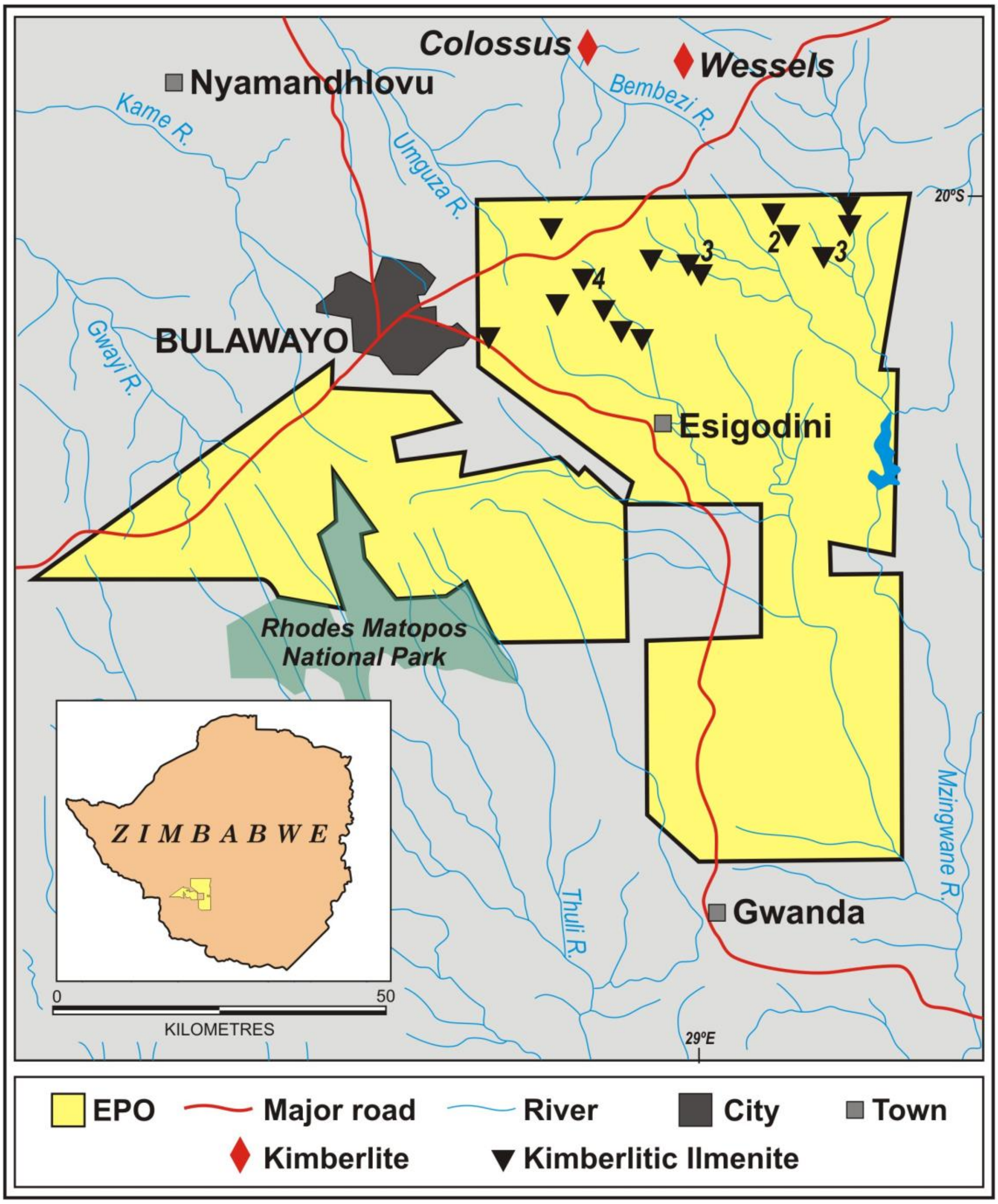


Fig. 3. Detail of the Bulawayo Block in relationship to the drainage system. Inverted triangles denote the sites of samples in which kimberlitic ilmenites were recovered. Numbers denote the numbers of >500µm ilmenites if more than one grain was present. Data from Moore (1998a & 1998b).

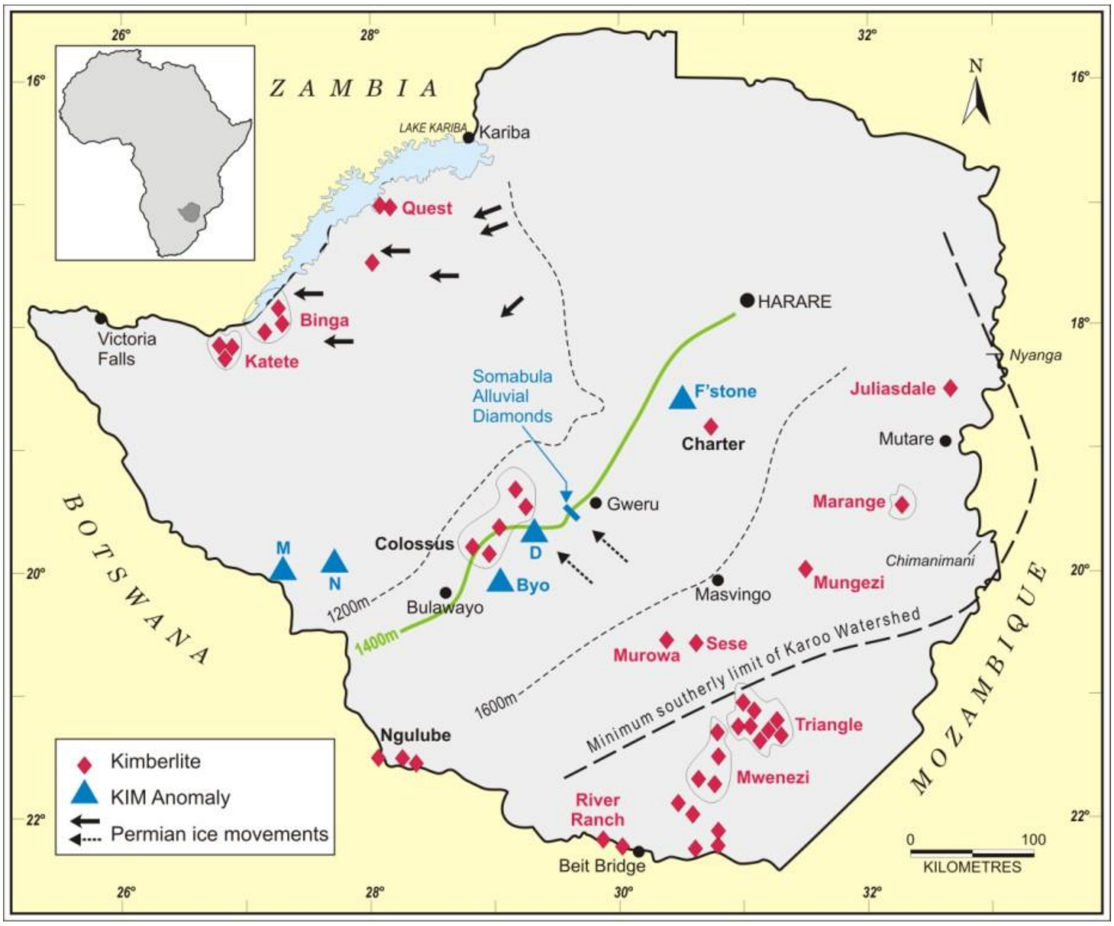


Fig. 4 Locations of known kimberlite clusters in Zimbabwe. Light-dashed and solid lines denote elevations in metres on the pre-Karoo surface (from Lister, 1987). The solid line (1400m) lies close to the modern watershed, Bold dashed line showing the minimum southerly limit of the Karoo watershed is from Moore et al., 2009b. Triangles denote unexplained kimberlitic heavy mineral anomalies. M = Maitengwe; N = Nanda; Byo = Bulawayo Block; D = Daiseyfield (From Moore, et al., 2009b). Solid black arrows show Permian ice movements summarized by Lister (1987); Dashed black arrows show Permian ice movements inferred by Moore and Moore (2006).

Fig. 5 Acacia savanna country on the senile watershed to the north of Bulawayo. Photo kindly provided by Darrel Plowes.

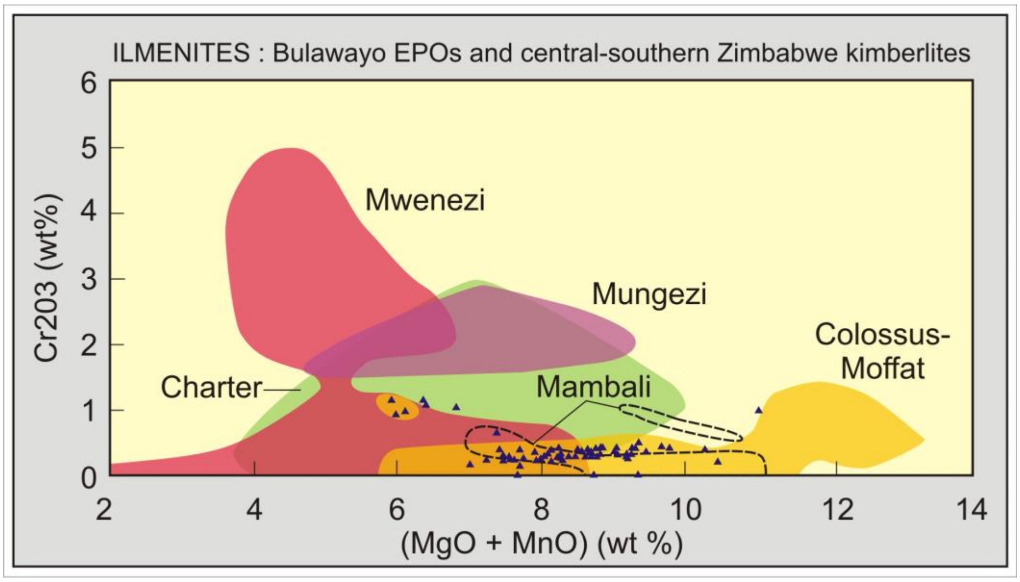


Fig. 6. Compositional fields for picroilmenites from kimberlites in south and central Zimbabwe in relationship to compositions of those from the Bulawayo Block (triangles). Sources of Data: Bulawayo Block: Moore, 1998 a&b; Charter Kimberlite: Brennan, 1999; Colossus-Moffat: Hildebrand, 1993; Mambali: Data kindly provided by Leon Daniels; Mungezi: Kimberlitic Searches (Pty.) Ltd/Somabula Explorations (Pty.) Ltd. Joint Venture, in house data; Mwenezi: Williamson and Robey, 1999.

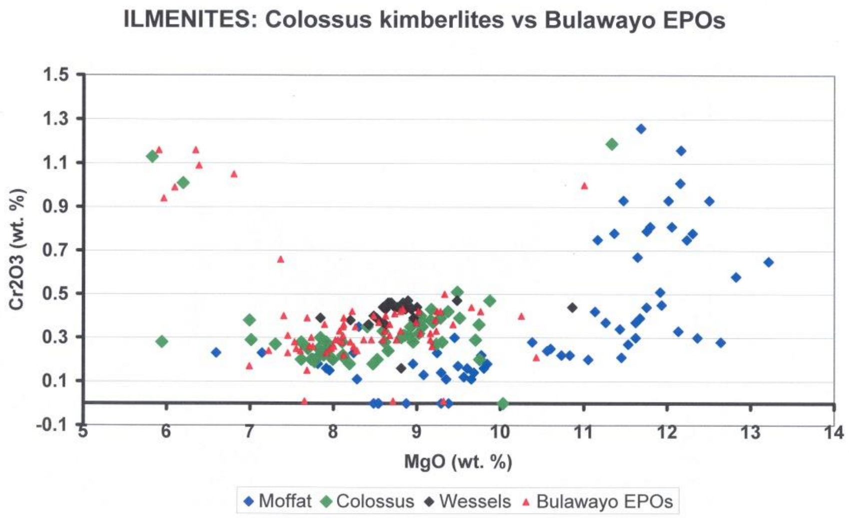


Fig. 7a. Comparison of chemical fields for ilmenites from the Bulawayo Block and kimberlites from the Colossus cluster. Sources of Data: Bulawayo Block: Moore, 1998a&b; Colossus, Moffat &Wessels: Hildebrand, 1993

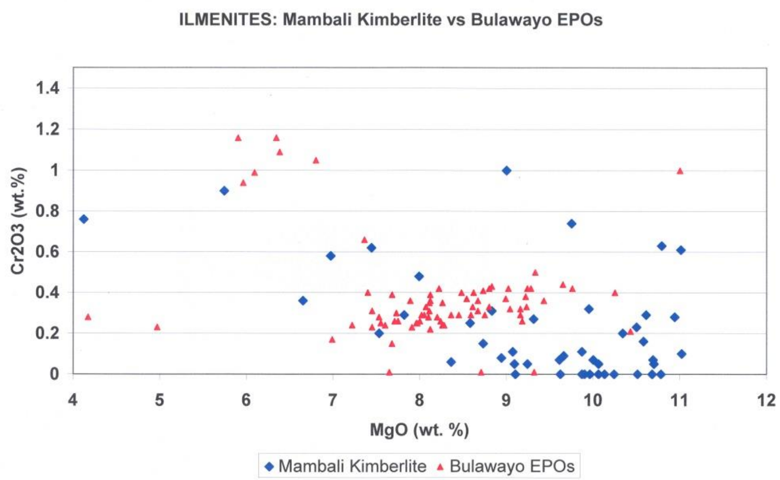


Fig. 7b. Comparison of chemical field for ilmenites from the Bulawayo Block and Mambali kimberlite, SW Zimbabwe. Sources of data: Bulawayo Block: Moore, 1998 a&b; Mambali kimberlite: Leon Daniels, Pers comm..