

Accretion and stabilisation of the Archaean Zimbabwe Craton (extended abstract)

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The evolution of the Zimbabwe Craton involved a number of crustal formation events. Each of these comprised the emplacement of a greenstone sequence and a related suite of granites (Wilson et al. 1995). The oldest nucleus of the craton is represented by the Tokwe Gneiss Complex and greenstones belonging to the Sebakwean Group, which formed ~ 3500 Ma ago. Subsequent crustal growth stages added greenstones of the Belingwean Supergroup (~ 2900 Ma) and lower Bulawayan Supergroup (2800 Ma) associated with the Chingezi Suite of granites (2900–2800 Ma), and the Upper Bulawayan (2700 Ma) and Shamvaian (2650 Ma) Supergroups associated with the Sesombi (2700 Ma) and Wedza (2650 Ma) Suites of granites. Stabilisation of the craton was achieved around 2600 Ma ago after the emplacement of large volumes of granites belonging to the Chilimanzi Suite, which was derived from crustal melt (Wilson et al. 1995; Jelsma et al. 1996). The rocks that formed during the 2700–2600 Ma events account for about 80% of all rocks exposed in the Zimbabwe Craton. Therefore, the large-scale geometrical pattern of the craton can be mostly attributed to events that occurred around this period. This pattern is characterised by numerous subelliptical batholiths locally separating keel-shaped greenstone belts.

Basal unconformities have been reported from a number of greenstone belts in Zimbabwe, with the most well-documented occurrences in the Belingwe Belt at the base of the Upper Bulawayan Supergroup along a siliceous sedimentary unit called the Manjeri Formation (Bickle et al. 1975). In the Belingwe Belt, unconformities separate four major greenstone sequences: the Lower and Upper Belingwean, and Lower and Upper Bulawayan Supergroups (Wilson et al. 1995). Each of these sequences is generally interpreted to be relatively undeformed, and the Belingwe Belt succession has been used to make stratigraphic correlations across most greenstone belts in Zimbabwe (Wilson

1979; Wilson et al. 1995), using the unconformities such as the one at the base of the Manjeri Formation, and their perceived correlatives, as major time markers.

Models for the evolution of the Zimbabwe Craton commonly assume deposition of greenstone sequences on continental crust, with crustal accretion and deformation fully explained by 'vertical' diapiric processes (e.g. Macgregor 1951; Ramsay 1989; Jelsma et al. 1993; Bickle et al. 1994; Wilson et al. 1995). The main observations in support of these models are the arcuate shapes of most greenstone belts enveloping circular gneiss domes and the presence of unconformities in a stratigraphic sequence that has been correlated across much of the craton. Considering evidence from the Yilgarn in Australia (e.g. Swager & Griffin 1990; Myers 1995), the Abitibi Belt in Canada (e.g. Card 1990) and the Kaapvaal Craton in South Africa (e.g. De Wit 1982), alternative interpretations for the Belingwe sequence have been suggested. Such interpretations involve the existence of regional layer-parallel shear zones that accommodated tectonic stacking of the Bulawayan sequence, with oceanic crust thrust onto continental margin material (Kusky & Kid 1992). Although all workers agree that layer-parallel shears exist, most workers in Zimbabwean greenstone belts suggest that stratigraphic repetitions are minor and probably the result of gravitational effects around the margins of rising granite domes (Jelsma et al. 1993). Much of the tectonic interpretation of greenstone belts in Zimbabwe, hinges on the recognition, interpretation and correlation of unconformities such as the one at the base of the Manjeri Formation in the Belingwe Greenstone Belt.

The Shamva-Bindura Greenstone Belt, 100 km NE of Harare, is a typical Zimbabwean arcuate greenstone belt that formed between 2720 and 2600 Ma (Wilson et al. 1995; Jelsma et al. 1996). All deformation in this belt has generally been related to diapirism of

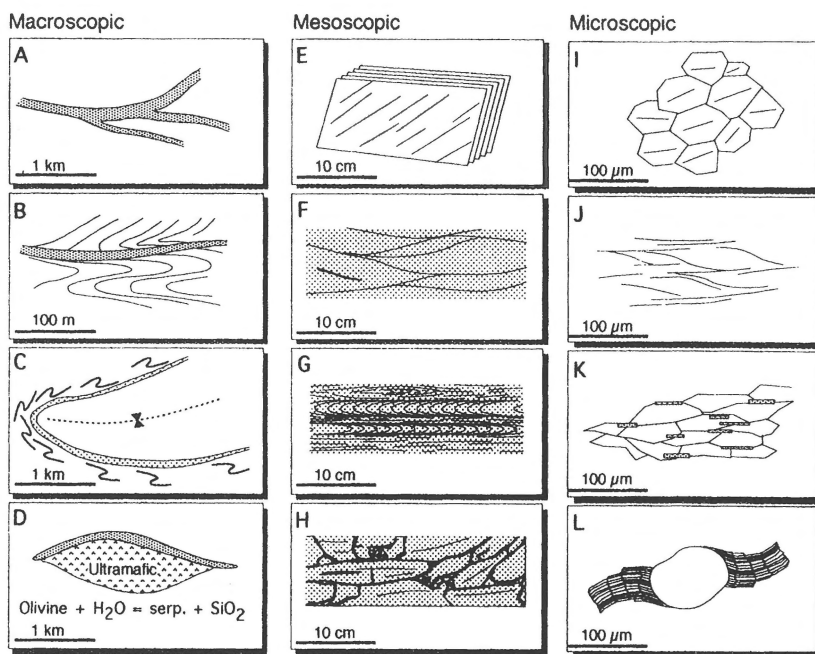


Figure 1. Summary of features that characterise silicified D_1 shear zones in the Shamra-Bindura Greenstone belt and that distinguish them from primary BIF or chert horizons. Macroscopic characteristics include: A) anastomosing and branching 'chert' horizons; B) 'chert' horizons that pass discordantly through folded country rock; C) fold vergences in 'chert' horizons that are independent of the greenstone keels; D) preferential occurrence of 'chert' horizons near serpentinised ultramafic units. Mesoscopic characteristics include: E) a penetrative foliation with or without a penetrative lineation; F) anastomosing foliation domains (commonly Fe-oxide or Fe-sulphide seams); G) intrafolial folds, sheath folds and transposition fabrics; H) brecciated 'chert' blocks infiltrated by Fe-oxide or Fe-sulphide seams. Microscopic characteristics include: I) strong quartz c-axes fabrics; J) s-c fabrics; K) grain-shape fabrics; L) asymmetric pressure fringes around clasts (chert fragments, pyrite cubes, etc.).

surrounding batholiths (Ramsay 1989; Jelsma et al. 1993), which affected a stratigraphic sequence interpreted to be largely undisturbed. Detailed structural-metamorphic observations in the belt are not consistent with this interpretation.

The earliest deformation geometries in the Shamva-Bindura Greenstone Belt, grouped as D_1 , involve a layer-parallel foliation that intensifies along an anastomosing network of narrow shear zones associated with a generally E-W trending mineral lineation. Many of the shears have been strongly silicified and are preserved as fine-grained (mylonitic) siliceous mica-schists infiltrated by iron-sulphides. They are commonly confused with deformed primary cherts or banded iron formations (BIFs; e.g. Stidolph 1977), and a number of the siliceous shears, e.g. the one separating the Arcturus and Iron Mask Formations, have been interpreted as regional unconformities (e.g. Wilson et al. 1995). The silicified shears preserve a number of characteristics that distinguish them from primary sedimentary horizons or BIFs. These characteristics are

summarised in Figure 1. The shears accommodated imbricate stacking of a pre-existing stratigraphy. In the absence of marker horizons, estimates of the amount of stratigraphic duplication cannot be made, but the intensity of mylonitic features in the shears indicates that displacements may have been large. The metamorphic grade during D_1 was variable with upper-amphibolite facies conditions affecting the lower parts of the stratigraphic sequence and lower-greenschist facies conditions the upper parts (Jelsma 1993), indicating high thermal gradients. In higher-grade parts of the belt the D_1 shear fabric is pervasive and associated with kilometer-scale isoclinal folds that are colinear with the mineral elongation lineation. Ni-mineralisation and granite intrusions accompanied this event.

D_1 structures are truncated by a complex array of discrete, greenschist-facies shears, that are associated with large-scale duplex geometries that could have resulted from strike-slip movements. This D_2 event is accompanied by the emplacement of sheet-like granite bodies and gold mineralisation.

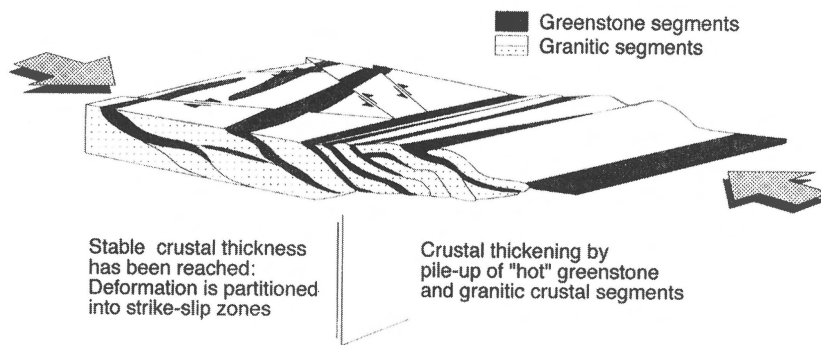


Figure 2. Possible scenario for the lateral accretion of the Shamva-Bindura Greenstone Belt resulting in isostatically stable continental crust. Further shortening of this crust is accommodated by strike-slip zones.

A third event, D_3 , involved the rise of the granite-gneiss domes that surround the Shamva-Bindura Greenstone Belt. This event resulted in the formation of shear zones marginal to the gneiss domes, in localised recumbent folding in the greenstones, and in a pervasive, amphibolite to greenschist facies contact-metamorphic overprint.

Available dates (Wilson et al. 1995; Jelsma et al. 1996) suggest that the greenstone sequence formed between 2720 and 2650 Ma, and that D_1 imbricate stacking was initiated around 2670 Ma and may have overlapped with, and graded into the D_2 events related to strike-slip movements between 2650 and 2620 Ma. The contact-metamorphic overprint and D_3 doming may have occurred around 2600 Ma, i.e. simultaneous with the emplacement of the Chilimanzi Granites (Jelsma et al. 1996).

A very similar deformation history as above, i.e. the formation of an early layer-parallel foliation and anastomosing shears, overprinted by strike-slip faults and a late contact-metamorphic assemblage, can be constructed for a number of greenstone belts in Zimbabwe. It is interesting to note that the correlatives of the Manjeri Formation and its basal unconformity, in for instance the Filibusu, Shangani and Bubi greenstone belts preserve all the characteristics of a silicified shear zone as given in Figure 1.

The structural and metamorphic sequence of events in the Shamva-Bindura Greenstone Belt puts important constraints on the tectonic evolution and final stabilisation of the Zimbabwe Craton between 2700 and 2600 Ma. Prior to D_1 compressional deformation, an extensional regime existed that allowed the lithospheric rise and emplacement of the large volumes of ultramafic and mafic material characteristic for the greenstone sequences. Crustal fragments during this extension-

al period may have been relatively thin (< 35 km) and characterised by very high geothermal gradients (e.g. metamorphic conditions were 700°C at 3 to 4 kbar; Jelsma 1993). Subsequent D_1 compressional deformation resulted in isostatically stable crust with a thickness of about 35 km, because limited exhumation occurred after D_1 (the cores of the Shamva-Bindura Greenstone Belt and other belts record metamorphic pressures of ~ 2 kbar, and much of the uplift can be attributed to neotectonic processes). Considering the layer-parallel shear zones that are associated with D_1 , and considering available data from other Archaean greenstone terrains including seismic reflection profiles (e.g. Ludden et al. 1993) it is logical to assume that D_1 deformation in the Shamva-Bindura Greenstone Belt involved the low-angle imbrication and lateral stacking of (relatively buoyant; Davies 1992) thin crustal segments to arrive at an isostatic equilibrium thickness for the crust (Figure 2).

The stacking of 'hot' crustal fragments during D_1 must have resulted in strongly disturbed crustal geotherms, with alternating 'hot' and 'cold' crustal sections that prevented the rise of large volumes of granite. It appears that ~ 35 km represented an equilibrium thickness during the late Archaean, beyond which further thickening could not occur. Instead, continued shortening of the ~ 35 -km-thick crust resulted in the partitioning of strain into D_2 strike-slip zones. Therefore, D_1 stacking or accretion and D_2 strike-slip may have operated simultaneously in different parts of the growing craton (Figure 2).

At the completion of D_1 stacking, the strongly disturbed crustal geotherm was restored to a new stable geotherm for crust composed of a stack of anomalously hot segments. It is anticipated that this equilibrium geotherm would have been anomalously high caus-

ing large parts of the crust (> 80%) to experience partial melting in places. This may have resulted in the emplacement of large volumes of granite and even convective-crustal overturn.

The advective rise of granite-gneiss domes can be explained as a direct and logical response to the establishment of a stable geotherm in 'new' continental crust that originated from the imbricate stacking of thin and hot crustal fragments. This process, together with the formation of large volumes of granitic melt represented by the Chilimanzi Granites, would have resulted in rapid cooling and thus stabilisation of the craton. Thus, vertical diapiric processes in the Zimbabwe Craton are an inevitable result of horizontal accretion.

References

- Bickle, M.J., A. Martin & E.G. Nisbet 1975 Basaltic and peridotite komatiites, stromatolites and a basal unconformity in the Belingwe Greenstone Belt, Rhodesia – *Earth Plan. Sci. Lett.* 27: 155–162
- Bickle, M.J., E.G. Nisbet & A. Martin 1994 Archaean greenstone belts are not oceanic crust – *J. Geol.* 102: 121–138
- Card, K.D. 1990 A review of the Superior Province of the Canadian Shield, a product of Archaean accretion – *Precamb. Res.* 48: 99–156
- Davies, G.F. 1992 On the emergence of plate tectonics – *Geology* 20: 963–966
- De Wit, M.J. 1982 Gliding and overthrust nappe tectonics in the Barberton Greenstone Belt – *J. Struct. Geol.* 4: 117–136.
- Jelsma, H.A. 1993 Granites and greenstones in Northern Zimbabwe: tectono-thermal evolution and source regions – Ph.D. Thesis, Free University, Amsterdam, 268pp
- Jelsma, H.A., P.A. van den Seek & M.L. Vinyu 1993 Tectonic evolution of the Bindura-Shamva greenstone belt (northern Zimbabwe): progressive deformation around diapiric batholiths – *J. Struct. Geol.* 15: 163–176
- Jelsma, H.A., M.L. Vinyu, P.J. Valbracht, G.R. Davies, J.R. Wijbrans & E.A.T. Verdurmen 1996 Constraints on Archaean crustal evolution of the Zimbabwe craton: a U-Pb zircon, Sm-Nd and Pb-Pb whole-rock isotope study – *Contrib. Mineral. Petrol.* 125: 55–70
- Kusky, T.M. & W.F.S. Kidd 1992 Remnants of an Archaean oceanic plateau, Belingwe Greenstone Belt, Zimbabwe – *Geology* 20: 43–46
- Ludden, J., C. Hubert, A. Barnes, B. Milkereit & E. Sawyer 1993 A three dimensional perspective on the evolution of Archaean crust: LITHOPROBE seismic reflection images in the southwestern Superior province – *Lithos* 30: 357–372
- Macgregor, A.M. 1951 Some milestones in the Precambrian of Southern Rhodesia – *Proc. Geol. Soc. S. Afr.* 54: 27–71
- Myers, J.S. 1995 The generation and assembly of an Archaean supercontinent: evidence from the Yilgarn craton, western Australia. In: M.P. Coward & A.C. Ries (eds) *Early Precambrian processes* – *Geol. Soc. Spec. Publ.* 95: 143–154
- Ramsay, J.G. 1989 Emplacement kinematics of a granite diapir: the Chinamora Batholith, Zimbabwe – *J. Struct. Geol.* 11: 191–209
- Stidolph, P.A. 1977 The geology of the country around Shamva – *Geol. Surv. Zimb. Bull.* 78
- Swager, C. & T.J. Griffin 1990 An early thrust duplex in the Kalgoorlie-Kambalda greenstone belt, Eastern Goldfields Province, Western Australia – *Precamb. Res.* 48: 63–73
- Wilson, J.F. 1979 A preliminary reappraisal of the Rhodesian basement complex In: C.R. Anhaeusser, R.P. Foster & T. Stretton (eds): *A symposium on mineral deposits and transportation and deposition of metals* – *Geol. Soc. S. Afr. Spec. Publ.* 5: 1–23
- Wilson, J.F., R.W. Nesbit & C.M. Fanning 1995 Zircon geochronology of Archaean felsic sequences in the Zimbabwe craton: a revision of greenstone stratigraphy and a model for crustal growth. In: M.P. Coward & A.C. Ries (eds): *Early Precambrian processes* – *Geol. Soc. Spec. Publ.* 95: 109–126