WHAT LIES BENEATH TABLE MOUNTAIN OR
ALL MODELS ARE WRONG, BUT SOME ARE USEFUL

Prof Alexander Kisters

August 2016

WHAT LIES BENEATH TABLE MOUNTAIN OR
ALL MODELS ARE WRONG, BUT SOME ARE USEFUL

Inaugural lecture delivered on 2 August 2016

Prof Alexander Kisters
Department of Earth Sciences
Faculty of Science
Stellenbosch University

Editor: SU Language Centre
Printing: SUN MeDIA
ISBN: 978-0-7972-1614-3

BIOGRAPHY

Professor Alexander (Alex) Kisters completed his geology undergraduate studies and MSc at the Aachen University of Technology (RWTH) in Germany and obtained a PhD in geology from the University of the Witwatersrand, Johannesburg. Subsequently, he had worked in the mineral exploration industry in South Africa and had held various postdoctoral and lecturer positions at the universities of Aachen, Cologne and the Witwatersrand before joining Stellenbosch University in 1999. Currently, he is appointed at the Department of Earth Sciences, University of Stellenbosch, as a professor in structural geology and tectonics where he teaches under- and postgraduate courses. He has supervised and cosupervised over 50 honours students, 15 MSc studies and 7 PhD studies. Alex has held a National Research Foundation rating for the past 15 years and a B-rating for the last five years. His research focuses on a range of topics related to crustal deformation aimed at integrating field data with regional tectonic models and more generic processes of melt transport and hydrothermal fluid flow in the Earth's crust.

ABSTRACT

The geological evolution of the Western Cape remains elusive after over 100 years of research. Based on regional fieldwork and correlations, this contribution aims to develop a tectonic model for the deposition and deformation of rocks of the Malmesbury Group, the rocks that underlie much of the Western Cape. The results point to the formation of the Malmesbury Group along an active continental margin. The internal structure of the Malmesbury Group reveals two main structurally overlying domains that represent a section through an accretionary prism. The lower domain is developed as a tectonic mélange. The structurally imbricated rocks record the offscraping of marine sediments and oceanic crust and their tectonic accretion to the base of the prism. The regionally widespread upper unit comprises mainly shallow-marine sediments and minor volcanic rocks. These rocks are interpreted as for-arc or slope-apron deposits overlying the prism along a major unconformity. The structural inventory suggests a two-stage evolution of the Malmesbury Group related to oblique, southeast-directed subduction. Early top-to-the-northwest thrusting and basal accretion in the subduction complex (D1 deformation phase) was succeeded by frontal accretion, upright transpressive folding, the development of large strike-slip faults and associated granite plutonism (D2 deformation phase). These results hint at a drastically different tectonic setting of the Malmesbury Group compared to currently discussed models and imply the need for a fundamental reclassification of the Malmesbury Group rocks and their geodynamic significance.

WHAT LIES BENEATH TABLE MOUNTAIN OR *ALL MODELS ARE WRONG, BUT SOME ARE USEFUL*

INTRODUCTION

The geology of the Western Cape is dominated by Table Mountain – the iconic slab of layered rock that towers above Cape Town. This highly visible piece of geology only forms a thin veneer. Much of the geology underlying the Western Cape is covered by the extensive blanket of younger rocks of the Cape Supergroup, including Table Mountain, or concealed by soils and vegetation, buried in wheatfields, meadows or vineyards. In fact, less than 2% of the surface area of the Western Cape exposes rocks that constitute this geological basement. Incomplete or poor rock exposure is common in geological work, but the extremely poor outcrop conditions in the Western Cape pose a challenge – how can we more or less reliably reconstruct what these rocks and rock associations mean, how they came about and how they fit into the greater scheme of things in southern Africa when only a tiny fraction of the rocks is accessible in a few widely scattered outcrops with no obvious links? It is, thus, not surprising that Western Cape geology is described and discussed by a number of often contradictory tectonic models that envisage rather diverse geodynamic settings for the geological evolution of the Western Cape.

The aim of this contribution is to present a more rigorous and, importantly, field-based characterisation of the geology and, specifically, structural evolution of rocks underlying the western parts of the Western Cape, collectively referred to as the Malmesbury Group (South African Committee for Stratigraphy [SACS], 1980). Much of this work is based on compilations of fieldwork intermittently done over the past 15 years in Stellenbosch. In most cases, the work was done by students and through student projects, which also highlights the relevance of field-based training for Stellenbosch geology students. The aim is to integrate different and seemingly conflicting rock assemblages, strains and strain paths of different parts of the Malmesbury Group into a coherent structural model that can be used to constrain the overall environment and setting in which the rocks were formed.

THE BROADER PICTURE

In tectonics, the term 'orogenic belt' is used to describe linear, somewhat arcuate, up to > 1 000 km long and 100 to 300 km wide zones in the continental crust that represent former plate boundaries and continental margins. Africa is crisscrossed by a number of these ancient orogenic belts, former mountain belts, now deeply eroded (Fig. 1). These belts record a typically cyclical evolution. The initial fragmentation of continents into smaller blocks along rift zones is followed by the formation of broader ocean basins along the original rifts. The subsequent closure of the oceans occurs above subduction zones, leading to the eventual collision and assembly of these continental fragments to form large continents, even supercontinents, again. We can identify at least three cycles of this continental breakup and reconfiguration in Africa dating back to some two billion years ago. Most geologists would agree that more and older orogenic cycles are preserved on the African continent, but the very old rock record becomes somewhat sketchy beyond this. The ancient sutures along which these movements have taken place are no longer manifested as mountain belts; millions of years of erosion have taken care of that. However, we know of these belts because they commonly expose deeply eroded parts of the lower continental crust that were pushed up to the surface during the collisional process. The trace of the belts is also often marked by granite plutons that indicate the heating and partial melting of lower crustal rocks to form upper crustal granites. First and foremost, the rocks caught up in between and along these collisional zones are intensely deformed. The rocks are folded and stretched, cleaved and rodded and sliced up and displaced by shear zones and faults. The detailed analyses of the deformed rocks, their evolution with time and their thermal characteristics allow us to reconstruct the path(s) that the rocks have taken, their origins and the overall geodynamic setting in which the rocks were formed.

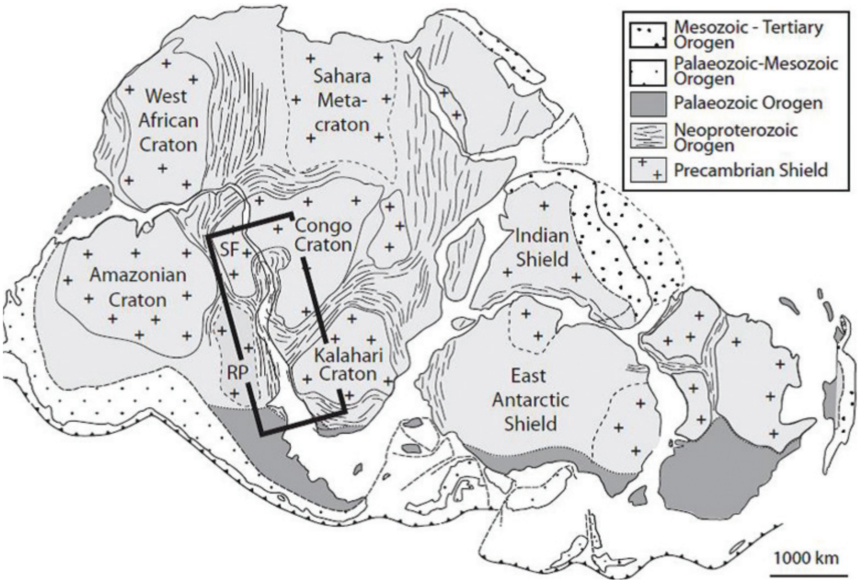

Figure 1: Map of the Gondwana supercontinent at ca. 530 million years ago showing the relative positions of continental nuclei (cratons and shields), welded together along younger orogenic belts. The black box outlines the original position of the Adamastor Ocean or proto-Atlantic that existed between South America and southern Africa ca. 750-540 million years ago. RP: Rio de la Plata Craton; SF: Sao Francisco Craton (from Gray et al., 2006).

In the Western Cape, the older, deeper geology underlying Table Mountain forms part of the so-called Saldania Belt, after the coastal town of Saldanha. The Saldania Belt, in turn, represents the southernmost extension of a much larger system of interconnected ca. 550-million-year-old orogenic belts in Africa, aptly termed the Pan-African orogenic system (Kennedy, 1964; Fig. 1). Pan-African belts north of the Saldania Belt include the much better exposed and studied coastal Gariep and Kaoko belts in northern South Africa and Namibia (Fig. 1). Similarly, old equivalents in South America are assigned to the Brasiliano orogenic system. This system of orogenic belts on either side of the Atlantic records the initial rifting and fragmentation of an older supercontinent, Rodinia, ca. 800-720 million years ago. The rifts developed into a wider oceanic basin, the Adamastor Ocean or proto-Atlantic, that separated continental fragments in South America from the large continental block of the Kalahari Craton in southern Africa (Fig. 1). From ca. 600 million years onwards, the Adamastor Ocean started closing again, bringing the South American and African continental fragments closer again along subduction zones. The oblique closure of the Adamastor Ocean progressed in a zipper-like fashion from north to south and culminated in the collision of the continental fragments to form the southern supercontinent of Gondwana ca. 550-500 million years ago (e.g. Hartnady et al., 1985; Gresse et al., 2006). The Malmesbury Group of the western Saldania Belt chronicles the later stages of this evolution, but this is where the consensus among geologists about the geological evolution of the Saldania Belt ends.

THE ROCKS BELOW TABLE MOUNTAIN – WHAT WE KNOW AND WHAT WE DO NOT KNOW

Rocks of the Malmesbury Group are largely marine sediments, shales and greywackes that were deposited in a near-shore to deep-water environment along the Adamastor Ocean (Hartnady et al., 1974; Von Veh, 1983; Theron et al., 1991; Fig. 1). While the Precambrian rocks are too old to have any fossil record, more recent geochronological studies have provided us with a reasonably good understanding of the timing of deposition of at least the exposed upper parts of the succession. Detrital zircons from the sedimentary rocks as well as U-Pb zircon crystallisation ages from intercalated volcanic units point to sedimentation and volcanism in the latest Neoproterozoic around ca. 560 Ma (Armstrong et al., 1998; Frimmel et al., 2013; Kisters et al., 2015). This age is similar to the deposition of the upper parts of the Gariep Supergoup in the Gariep Belt to the immediate north, an aspect that has been used to draw direct correlations between rocks of the Malmesbury Group and rocks in the Gariep

Belt to the immediate north (Frimmel, 2009; Frimmel et al., 2013). The thickness of the Malmesbury Group is only very poorly constrained, and neither the top nor the base of the sequence is exposed. However, important information about the depth extent of the Malmesbury Group comes from the Cape Granite Suite. The composition, structures, isotope characteristics and age of deep-crustal, high-grade metamorphic wall-rock xenoliths in the granites are similar to that of the Malmesbury Group exposed at surface (e.g. Villaros et al., 2009; Harris and Vogeli, 2010). This points to a thickness of the Malmesbury Group in excess of 25 km and about 10 times the thickness of the Gariep Supergroup to the north (Fölling et al., 2002), suggesting a fundamentally different environment of deposition for the two.

Structurally, rocks of the Malmesbury Group are folded into northerly to northwest-trending, doubly plunging and more or less upright or southwest-verging folds. These folds are ubiquitous throughout the western Saldania Belt and are designated F2 folds. An earlier fold generation (F1 folds) is preserved in the cores of regional-scale F2 antiforms in the central parts of the western Saldania Belt that expose the structurally deeper parts of the Malmesbury Group. These F1 folds are mainly recumbent, isoclinal, intrafolial folds that pervasively refold and overprint original bedding features. Most regional studies focus on the presence and significance of the regional-scale, northwest-trending strike-slip faults of the Colenso and Piketberg-Wellington faults (Fig. 2). These major, up to several kilometre-wide fault zones are commonly thought to separate three structurally and lithologically distinct domains or terranes, including the southwestern Tygerberg, central Swartland and northeastern Boland terranes (Hartnady et al., 1974; SACS, 1980).

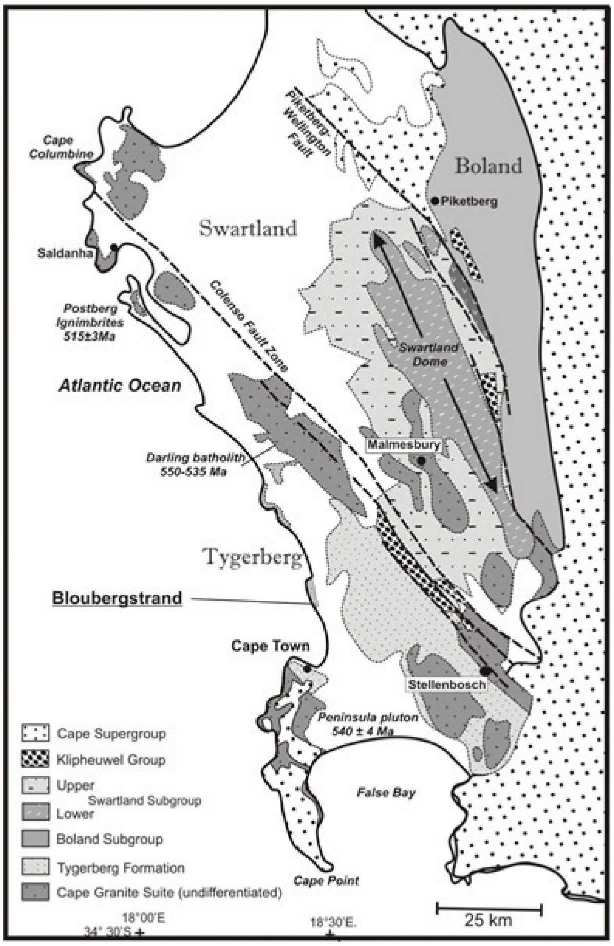

Figure 2: Simplified geological map of the western Saldania Belt in the Western Cape (from Kisters et al., 2015; simplified after Theron et al., 1991).

The term 'terrane' in particular implies that the three domains represent formerly unrelated or exotic crustal blocks that were juxtaposed and welded together along the major fault zones during the later stages of crustal convergence and collision. Accordingly, rocks of the Malmesbury Group are commonly discussed and subdivided relative to their position in one of the three fault-bounded domains (SACS, 1980; Gresse et al., 2006). This is not without problems. Regional field studies have maintained that the rocks are similar or show gradational contacts across and on either side of the faults (Von Veh, 1983; Theron et al., 1991; Belcher, 2003). Similarly, there are no sharp metamorphic or structural breaks that should be expected across the faults. Moreover, the age of sedimentation in the three domains is rather similar and can be constrained to the latest Neoproterozoic between ca. 600 and 550 Ma (Armstrong et al., 1998; Frimmel et al., 2013; Kisters et al., 2015). Lastly, the two faults are late-stage features in the overall evolution of the Malmesbury Group. The faults deform the Malmesbury Group but are not responsible for the formation of the rocks.

DECONSTRUCTING THE PAN-AFRICAN ROCKS OF THE WESTERN SALDANIA BELT

From the above, it is clear that a classification and subdivision of the Malmesbury Group into three tectonostratigraphic, fault-bounded packages is hardly suited to explaining the origin and geodynamic setting of the rocks (Belcher and Kisters, 2003). Instead, a meaningful subdivision and discussion aimed at understanding the origin and setting of the rocks should focus on (1) lithological assemblages and their meaning for depositional environments and (2) the internal architecture and retro-deformation of the rocks aimed at characterising the process that led to the assembly of the Malmesbury Group and its present-day configuration.

This is where early regional works on the Malmesbury Group provide some key observations (Rabie, 1948; Newton, 1966). Instead of subdividing the Saldania Belt into three adjacent domains with supposedly distinct tectonostratigraphic packages, these early studies identified two structurally overlying units, henceforth termed the lower unit and the upper unit. Exposures of the lower unit, in particular, are only very sporadic and confined to the cores of regional-scale antiforms, such as the Swartland dome (Fig. 2) in the central Swartland domain (Belcher, 2003; Gresse et al., 2006). Rocks of the upper unit are developed throughout the western Saldania Belt and across the regional strike-slip faults, from Gordons Bay in the South through to Cape Town and to St Helena Bay in the far north and Porterville in the east. The contact between the lower and upper units must be sharp, but it is nowhere exposed (Belcher, 2003). Based on the abrupt change in structural styles and lithological inventory, this contact has been suggested to be either a major structural detachment (Rabie, 1948) or an unconformity (Belcher and Kisters, 2003).

THE LOWER UNIT

For the most part, rocks of the lower unit contain quartz-sericite phyllites, chlorite-sericite schists, minor quartzites and cherts and local carbonate units of highly varying thickness, often graphitic. The mafic metavolcanic units of the Bridgetown Formation are also considered part of this lower unit. Despite the pervasive alteration of the rocks, geochemical characteristics of the mafic metavolcanics point to an origin of the rocks as oceanic crust (Slabber, 1995). Similar but smaller metamafic lenses are found elsewhere, mainly in structural contact and imbricated with phyllites and chlorite schists of the lower unit (Belcher, 2003).

The structural complexity and lithological heterogeneity are best appreciated in quarry operations that provide three-dimensional windows into the lower unit (Belcher, 2003; Belcher and Kisters, 2003). Primary sedimentary features and bedding have largely been obliterated by isoclinal, intrafolial recumbent folds and a pervasive subhorizontal phyllitic cleavage (S1). Contacts between thicker lithological packages are commonly sheared, and the low-angle truncation of bedding indicates the structural nature of contacts (Hartnady et al., 1974; Belcher and Kisters, 2003). Kinematic indicators consistently point to top-to-the-west and northwest kinematics. The widespread structural contacts between lithological packages agree with the discontinuous extent of most formations and the only limited correlation of units on a regional scale that has previously also been suggested to be the result of a tectonic interleaving and imbrication of the rocks (Hartnady et al., 1974; Belcher, 2003; Gresse et al., 2006). Quartz veins are abundant and may constitute up to 20% of the rock volume throughout the lower unit, attesting to pervasive fluid flow during deformation. The majority of quartz veins have been transposed into the S1 foliation during progressive deformation. High-angle intersecting quartz and quartz-carbonate veins are preserved in more competent blocks such as limestones. These brittle vein networks and hydrothermal breccias not only illustrate the original geometry of fluid-plumbing systems but also delineate discrete zones of paleoseismicity.

The pervasive bedding transposition, S1 foliation development and syn-tectonic veining characterise the earliest deformation event (D1) of rocks in the lower parts of the Malmesbury Group in the western Saldania Belt. Fabrics (S1 and L1) and structures (boudinage and vein orientations) indicate that rocks of the lower unit have experienced vertical shortening and horizontal (northwest-southeast) stretching strains throughout this deformation. The resulting structural pattern for the lower units is that of a tectonic mélange in which oceanic sediments – shales, greywackes, limestones and cherts – are imbricated with slivers of oceanic crust during top-to-the-west and northwest thrusting. The mélange-like character is evident on an outcrop scale, best observed in quarry operations, but also on a regional scale, manifest by the lack of regionally traceable marker horizons or correlation of units.

THE UPPER UNIT

In contrast to the lower unit, primary structures and bedding in the upper unit are well preserved. Most workers agree on the metaturbiditic origin of the interlayered shale-greywacke successions (e.g. Von Veh, 1983; Theron et al., 1991). Good exposures of rocks of the upper unit are found north of Cape Town, in the Tygerberg Hills and along the Atlantic coast, in the Strand and Gordons Bay area around False Bay but also farther inland along road cuts. In the western parts of the Saldania Belt, these rocks have been grouped together as the Tygerberg Formation. Most sedimentological studies hint at relatively shallow-water depositional environments for much of the Tygerberg Formation. This includes the massive greywacke units of the Tygerberg Formation in the Tygerberg Hills where intercalated conglomerates suggest both shallow-water depositional conditions and a proximal source of the sediments. Soft-sediment deformation structures and thick psammite units also indicate rapid sedimentation (Theron et al., 1991). The intercalated amygdaloidal lavas and tuff horizons at Bloubergstrand mark intermittent episodes of volcanism (Von Veh, 1983). The textures of the lavas and tuffs point to even subaerial conditions of the local volcanism (Von Veh, 1983; Kisters et al., 2015). However, deeper water conditions are indicated by the shale-dominated and channel-fill deposits farther north along the Atlantic coast, around Ganzekraal and Grotto Bay. Taken in conjunction, rocks previously grouped under the Tygerberg Formation indicate shallow-water (in the south) to deep-water (in the north) depositional environments with a not-too-distant source and a hinterland mainly located to the east (e.g. Von Veh, 1983). This trend is continued in the eastern parts of the Boland domain where sediments are increasingly immature and coarser grained (Gresse et al., 2006) and often intercalated with metavolcanic rocks (Hartnady et al., 1974). The volcano sedimentary succession of the Boland domain has been likened to a fluvio-marine, deltaic and near-shore depositional environment with a close-by continental hinterland located to the east and northeast (e.g. Gresse et al., 2006).

Structurally, rocks of the upper unit are relatively simple. The main and ubiquitous structural features are upright to southwest-verging F2 folds. F2 folds show northerly to northwesterly trends and are associated with a broadly axial planar, more or less upright foliation (S2). Rowe et al. (2010) showed this foliation to be a transecting cleavage, indicating F2 folding during sinistral transpression. The transecting geometry of the S2 foliation with respect to F2 folds is regional. Early D1 structures are not developed, and individual packages can be correlated over larger distances in the upper unit without major structural disruptions. Contacts between formations are rather gradational, and formations also cut across the regional strike-slip faults. Importantly, D2 fabrics (F2 folds and S2 foliation) deform and postdate earlier D1 fabrics of the lower unit. Small-scale D2 structures (quartz veins, boudinage and small-scale faults) indicate subhorizontal northeast-southwest shortening and an orthogonal, fold-hinge parallel northwesterly extension during D2.

The northwest-trending, subvertical Colenso and Piketberg-Wellington faults (Fig. 2) are the largest structural feature in the western Saldania Belt. Deformation along the Colenso fault, the more prominent of the two, is distributed defining an up to eight kilometre-wide fault zone that can be traced for > 150 km from Northwest Bay to east of Stellenbosch where it is covered by the younger Cape Supergroup (Kisters et al., 2002). Better exposed parts of the Colenso Fault are restricted to granites of the Cape Granite Suite whereas much of its trace in the deeply weathered Malmesbury Group is only indicated by massive positively weathering quartz veins or quartz-veined breccias. Intrusive and fabric relationships in the Darling batholith document the synmagmatic deformation of successively emplaced granite phases along the Colenso Fault (Kisters et al., 2002). Available geochronological data indicate deformation to have occurred over a period of at least 25 million years, between 545 and 520 million years ago, thus recording relatively late-stage increments of the regional deformation (D2). Shear-sense indicators in the deformed, often mylonitic granites and gneisses overwhelmingly point to sinistral kinematics. Strains indicate a subhorizontal east-west-orientated shortening and northwesterly orientated stretching, similar to D2 strains recorded for the F2 folding. Strike-slip shearing and regional F2 folding are thus part of the overall regional D2 strain pattern, accommodating strain partitioning during sinistral transpressive deformation related to the oblique shortening (D2) and during the later stages of regional deformation and closure of the Adamastor Ocean. This strain pattern seems in marked contrasts with the vertical D1 shortening strains recorded for the earlier D1 deformation in the lower unit.

DISCUSSION

The ubiquitous F2 folding and sinistral strike-slip shearing along the main fault zones underline the overall sinistral transpressive kinematics in the belt related to the oblique closure of the Adamastor Ocean in the latest Neoproterozoic (e.g. Hartnady et al., 1985). These similarities and the similar age structure of rocks of the Malmesbury Group and the Gariep Supergroup are commonly invoked to indicate the lithological and structural continuity between the coastal Saldania and Gariep belts (e.g. Frimmel, 2009; Rapela et al., 2011; Frimmel et al., 2013). These models suggest a structural evolution related to the oblique closure of a back-arc basin situated behind a magmatic arc, the Dionisio Cuchilla-Pelotas arc (Frimmel et al., 2013), now situated in Brazil and Uruguay. However, the lithological inventory and thickness of the Malmesbury Group, the late-tectonic intrusion of the voluminous Cape Granite Suite, the structural inventory and presence of distinct structural domains together with the uniformly low metamorphic grade are distinct. This would rather point to distinctly different evolutions and geodynamic settings of the two adjoining belts.

The subdivision of the Malmesbury Group into a structurally and lithologically distinct lower and an upper unit can be used to formulate an alternative model for the tectonic and depositional setting of the western parts of the Saldania Belt. Both the lithological inventory and structural evolution are consistent with the formation and progressive deformation of the Malmesbury Group along an active continental margin. In this scenario, the lower and upper unit of the Malmesbury Group represent a cross-section through an accretionary wedge, not a back-arc sequence. The lower unit represents a tectonic mélange that records the offscraping and imbrication of marine sediments and slivers of oceanic crust. Top-to-the-west and northwest kinematics in the lower unit are consistent with an imbrication of the rocks during oblique, southeast-directed subduction of the Adamastor Ocean below the African continent. The vertical shortening and horizontal stretch are consistent with the underthrusting and basal accretion of the rocks to the base of this accretionary complex. Abundant quartz and quartz-carbonate veining throughout the lower unit document the progressive dewatering of initially water-saturated sediments during burial and basal accretion. Lithostatic and episodically supralithostatic fluid pressures are indicated through the presence of hydraulic breccias and pervasive vein networks that have assisted thrusting and the imbrication of units to the base of the prism.

The sedimentology and deformation of the upper unit mark a sharp break compared to the underlying mélange of the lower unit. Sedimentary rocks point to mainly shallow-water conditions of deposition and, in places, fluvio-marine conditions. Volcanic intercalations are recorded from the western Tygerberg Formation and the eastern Boland Subgroup. Taken in conjunction, these features agree with the deposition of the rocks in a fore-arc basin overlying the accretionary prism of the lower unit. Shale-dominated units and channel-fill deposits in the northern Tygerberg Formation suggest deeper water sedimentation and may relate to slope-apron deposits on the ocean-facing slope of the accretionary prism. This scenario of a lower mélange unit formed by offscraping above a subbducting slab unconformably overlain by fore-arc and slope-apron deposits can account for the lack of early D1, imbrication-related fabrics in the upper unit. However, F2 folding and D2 strike-slip shearing still record the sinistral shortening during oblique convergence and closure of the Adamastor Ocean. In other words, the seemingly different strains, strain paths and kinematics recorded in the upper and lower units merely reflect two different structural stockworks in the accretionary wedge – the lower unit formed during basal accretion during southeastward subduction, and the upper unit records oblique, frontal shortening during this subduction. D2 structures throughout the western Saldania Belt indicate the pronounced partitioning of the oblique shortening into a coaxial shortening component, accommodated by the ubiquitous F2 folds, and noncoaxial simple shear, accommodated by the regional-scale strike-slip faults.

Models that have invoked a fore-arc regional setting for the western Saldania Belt and the Malmesbury Group are not new but have previously lacked a rigorous integration of sedimentological and structural studies. The fore-arc setting can also explain the late-tectonic emplacement of the Cape Granite Suite, related to slab delamination and detachment following the main phase of subduction. Notably, rocks of the Saldania Belt seem to have escaped a major collisional event. The low-grade metamorphic conditions of the Malmesbury Group do not indicate any substantial thickening and subsequent isostatic uplift of the rocks. Similarly, convergent structures are remarkably well preserved and have not experienced an overprint by collisional fabrics. This points to a rather soft collision of the southern tip of the African with the South American continental block compared to the northern belts.

CONCLUSIONS

Models pertaining to the tectonic evolution of the western Saldania Belt rely on a very thin database, and poor outcrop conditions require the interpolation of results over kilometres and tens of kilometres between exposures. In this contribution, I have tried to compile and integrate the results of many years of intermittent fieldwork into a more coherent tectonic model that can account for the lithological and structural characteristics of the Malmesbury Group rocks. There are many outstanding issues that will have to be addressed in order to refine or redefine tectonic models for the western Saldania Belt. These include detailed sedimentological studies throughout the belt, metamorphic work on the lower unit rocks or geochronological studies on volcanic units intercalated with the Malmesbury Group sediments. Recent work on granites on the Cape Granite Suite has already yielded important insights into the depth extent of the Malmesbury Group and deeper crustal processes operating way below the currently exposed levels. The integration of these results will undoubtedly lead to more complete models for the Saldania Belt, also with regard to its broader geological setting within the Pan-African system of orogenic belts.

ACKNOWLEDGEMENTS

This work was conducted in close collaboration with many Stellenbosch geology students over a period of over 15 years. I thank these students for their enthusiasm and diligence, for sharing their results and for contributing to our knowledge of Western Cape geology.

REFERENCES

Armstrong, R., De Wit, M.J., Reid, D., York, D. and Zartman, R., 1998. Cape Town's Table Mountain reveals rapid Pan-African uplift of its basement rocks. Journal of African Earth Science, 27, 1A, 10.

Belcher, R.W., 2003. Tectonostratigraphic evolution of the Swartland region and aspects of orogenic lode-gold mineralisation in the Pan-African Saldania Belt, Western Cape, South Africa. Unpublished PhD thesis, Stellenbosch University, South Africa.

Belcher, R.W. and Kisters, A.F.M., 2003. Lithostratigraphic correlations in the western branch of the Pan-African Saldania Belt, South Africa: the Malmesbury Group revisited. South African Journal of Geology, 106, 327-342.

Fölling, P.G., Zartmann, R.E. and Frimmel, H.E., 2002. A novel approach to double-spike Pb-Pb dating of carbonate rocks: examples from Neoproterozoic sequences in southern Africa. Chemical Geology, 171, 97-122.

Frimmel, H.E., 2009. Configuration of Pan-African orogenic belts in southwestern Africa. In: C. Gaucher, A.N. Sial, G.P. Halverson and H.E. Frimmel (Editors), Neoproterozoic-Cambrian tectonics, global change and evolution: a focus on southwestern Gondwana. Developments in Precambrian Geology 16, Elsevier, The Netherlands, 145-151.

Frimmel, H.E., Basei, M.A.S., Correa, V.X. and Mbangula, N., 2013. A new lithostratigraphic subdivision and geodynamic model for the western Pan-African Saldania Belt, South Africa. Precambrian Research, 231, 218-235.

Gray, D.R., Foster, D.A., Goscombe, B., Passchier, C.W. and Trouw, R.A.J., 2006. 40R/39Ar thermochronology of the Pan-African Damara orogeny, Namibia, with implications for tectonothermal and geodynamic evolution. Precambrian Research, 150, 49-72.

Gresse, P.G., Von Veh, M.W. and Frimmel, H.E., 2006. Namibian (Neoproterozoic) to early Cambrian successions. In: M.R. Johnson, C.R. Anhaeusser and R.J. Thomas (Editors), The geology of South Africa. Geological Society of South Africa/Council for Geoscience, South Africa, 395-420.

Harris, C.J. and Vogeli, J., 2010. Oxygen isotope composition of garnet in the Peninsula granite, Cape Granite Suite, South Africa: constraints on melting and emplacement mechanisms. South African Journal of Geology, 113, 401-412.

Hartnady, C.J.H., Joubert, P. and Stowe, C.W., 1985. Proterozoic crustal evolution of southwestern Africa. Episodes, 8, 236-244.

Hartnady, C.J.H., Newton, A.R. and Theron, J.N., 1974. The stratigraphy and structure of the Malmesbury Group in the southwestern Cape. Bulletin of the Precambrian Research Unit, University of Cape Town, South Africa, 15, 193-213.

Kisters, A.F.M., Agenbach, C. and Frei, D., 2015. Age and tectonic significance of the volcanic Bloubergstrand Member in the Pan-African Saldania Belt, South Africa. South African Journal of Geology, 118, 213-224.

Kisters, A.F.M., Belcher, R.W., Armstrong, R.A., Scheepers, R., Rozendaal, A. and Jordaan, L.S., 2002. Timing and kinematics of the Colenso Fault: the Early-Paleozoic shift from collisional to extensional tectonic in the Pan-African Saldania Belt, South Africa. South African Journal of Geology, 105, 257-270.

Newton, A.R., 1966. Preliminary work on Malmesbury rocks. 4th annual report, Precambrian Research Unit, University of Cape Town, 16-17. Rabie, L.P., 1948. Geological map of the Moorreesburg-Wellington area: Stellenbosch University.

Rapela, C.W., Fanning, M.C., Casquet, C., Pankhurst, R.J., Spalletti, C., Poire, D. and Baldo, E.G., 2011. The Rio de la Plata Craton and adjoining Pan-African/Brasiliano terranes: their origin and incorporation into southwest Gondwana. Gondwana Research, 20, 673-690.

Rowe, C.D., Backeberg, N.R., Van Rensberug, T., McLennan, S.A., Faber, C., Curtis, C. and Viglietti, P.A., 2010. Structural geology of Robben Island: implications for the tectonic environment of Saldanian deformation. South African Journal of Geology, 113, 57-72.

Slabber, N., 1995. The geology and geochemistry of the Bridgetown Formation of the Malmesbury group, Western Cape Province. Unpublished MSc thesis, Stellenbosch University, South Africa.

South African Committee for Stratigraphy (SACS)., 1980. Stratigraphy of South Africa. Part 1 (Comp. L.E. Kent). Lithostratigraphy of the Republic of South Africa, southwest Africa/Namibia, and the republics of Bophuthatswana, Transkei and Venda. Handbook of the Geological Survey of South Africa, 8.Geological Society of South Africa.

Theron, J.N., Gresse, P.G., Siegfried, H.P. and Rogers, J., 1991. The geology of the Cape Town area. Explanation Sheet 3318. Department of Mineral and Energy Affairs, Geological Survey, South Africa.

Villaros A., Stevens G. and Buick I.S., 2009. Tracking S-type granite from source to emplacement: clues from garnet in the Cape Granite Suite. Lithos, 112, 217-235.

Von Veh, M.W., 1983. Aspects of sedimentation, structure and tectonic evolution in the Tygerberg Terrane, southwestern Cape Province. Bulletin of the Precambrian Research Unit, University of Cape Town, South Africa, 32.