



Structures at the base of the Upper Group 2 chromitite layer, Bushveld Complex, South Africa, on Karee Mine (Lonmin Platinum)

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Abstract

Exposures in a now-infilled pit mined for platiniferous UG2 chromitite in the Bushveld Complex, South Africa, are described. The layer of chromitite is underlain by anorthosite, providing a dramatic colour contrast. The interface between these two rock types shows evidence of various scales of irregularities. In plan view, small circular depressions, less than 3 cm across and 5 mm deep, occupy about 20% of the surface. Between them, the contact is planar. The anorthosite, immediately underlying the chromitite, has a planar fabric visible in thin sections that is not disturbed beneath these small depressions. Another set of depressions occurs, about 40 cm in diameter and with variable depth (< 40 cm). Again they are approximately circular. Larger structures, called potholes, reach several metres. No regular distribution pattern is apparent in any of these structures.

Several possible processes are reviewed for the origin of these irregularities, especially the small-scale structures, but none explains all the features noted. These processes include remelting, diapirism, impact-generated dimpling, gas escape, and interference rippling. We present a photographic record of these structures, but present no definitive model for their interpretation.

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1. Introduction

The accumulation mechanisms of layers in large mafic igneous complexes can be likened to sedimentary processes, either clastic or chemical (Naslund and McBirney, 1996). As with sedimentary rocks, they are therefore liable to experience periods of non-deposition and erosion, producing nonconformities,

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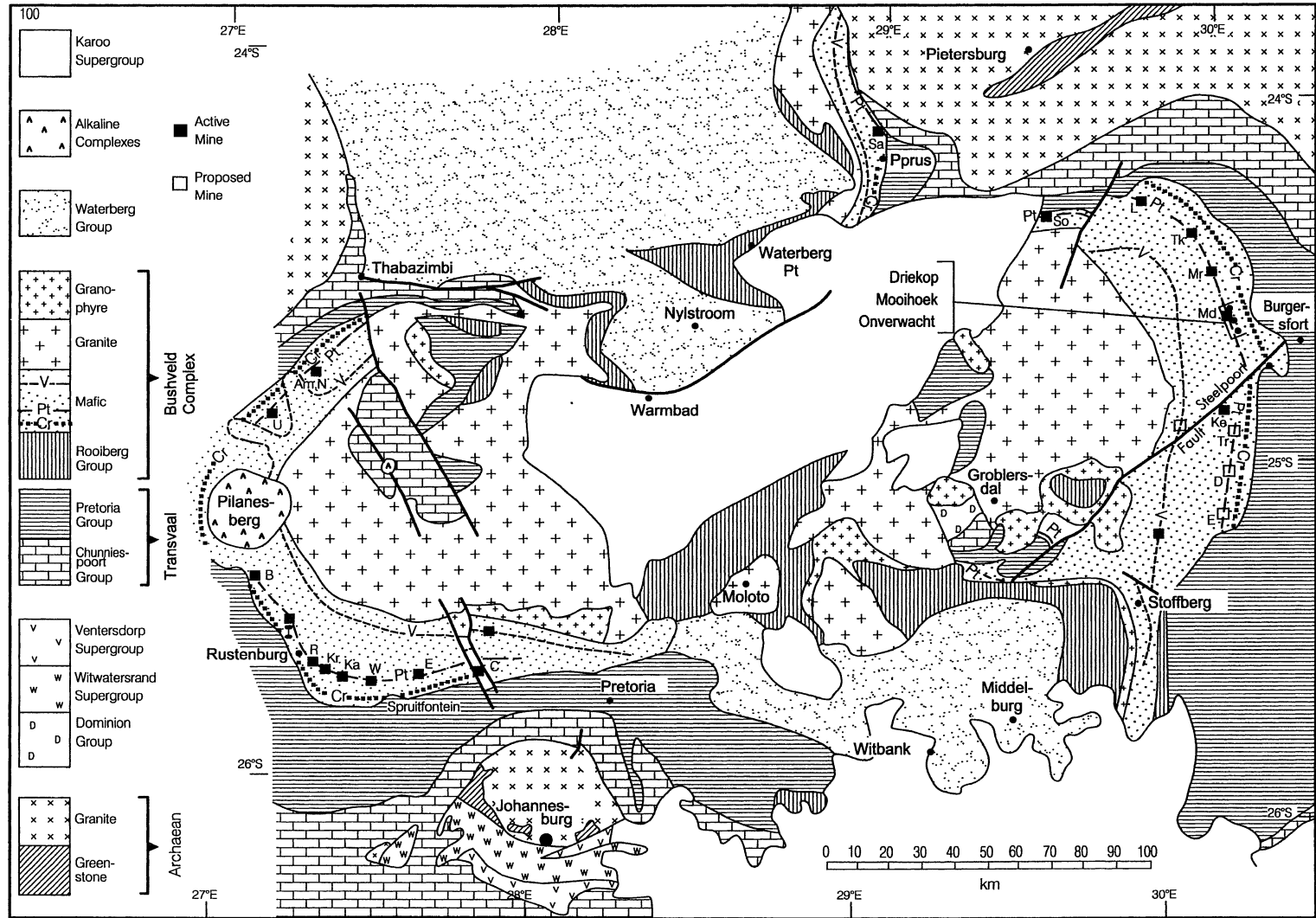


Fig. 1. General geological map of the Bushveld Complex (adapted from many sources given by Eales and Cawthorn, 1996). All the platinum mines (Merensky and UG2 Reefs) are denoted by squares (open squares—planned mines). The locality of Karee Mine is indicated as Ka, east of Rustenburg.

disconformities, or unconformities. The presence of angular unconformities and so-called “beheading” of cyclic units are examples that have been documented to support such processes. For example, in the Bushveld Complex, South Africa, a number of cyclic units have been recognized (Cameron, 1982), each starting with a chromitite layer, and it has been generally assumed that such cycles are initiated by addition and mixing of magma (Brown, 1956; Jackson, 1970; Irvine, 1977). In many sections, the complete cycle is not preserved (Eales et al., 1988), which may be either the result of non-deposition or thermochemical erosion. If the new magma was hotter than the resident magma, thermal erosion may have taken place (Campbell, 1986). Injection or lateral flow of viscous magma could have caused mechanical erosion. Loading of cumulates by magma addition could have caused instability, as observed in dams, and could also have led to disruption and slumping of the uppermost layers (Carr et al., 1994). Incomplete cyclic units could result from either, or a combination of both, of these processes. Various features observed at the base of chromitite layers, such as potholes (first documented by Schmidt, 1952), have been considered to be the result of such processes. Potholes are subcircular features that sharply cut through the planar layering of their footwall.

The Upper Group 2 (UG2) chromitite layer and the Merensky Reef (which also has a basal, but thin, chromitite layer) have been extensively mined for platinum-group elements, and so various aspects, such as the presence of potholes, have been documented (Cousins, 1969; Vermaak, 1976; Campbell, 1986; Carr et al., 1994). However, because potholed areas are difficult to mine, they may be left behind during mining operations, and hence the exact geometry is not always easy to reconstruct from underground sections. At Karee Mine (part of Lonmin Platinum operations, east of Rustenburg) in the western Bushveld, open-pit mining has recently been undertaken on the UG2 chromitite (Fig. 1). The footwall to the UG2 here is a very robust anorthosite, and the upper contact of the anorthosite has been perfectly exposed in large pavements and provides a perfect opportunity to document the detailed topology of possible erosional features.

2. General geology of the Bushveld Complex

The Bushveld Complex is the world’s largest layered intrusion (Fig. 1), and contains almost limitless resources of platinum-group elements, chromium, and vanadium (Eales and Cawthorn, 1996). It has been subdivided into various zones on the basis of major mineralogy (Fig. 2). It is the Upper Critical Zone, with its cyclic layering (Cameron, 1982), that is the focus of this paper. An idealized cycle consists of a basal chromitite, followed by pyroxenite (and possibly harzburgite), norite, and finally anorthosite

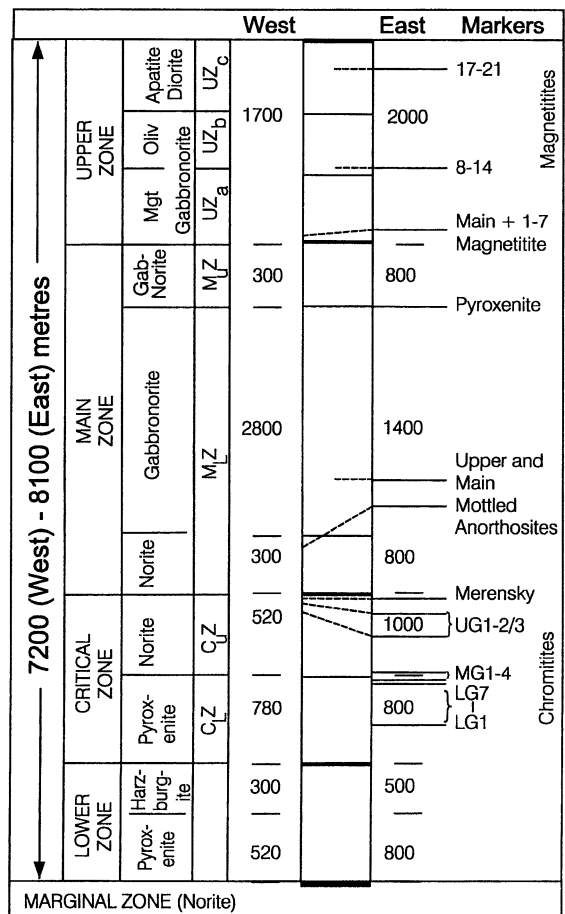


Fig. 2. Simplified stratigraphic section through the east and west limbs of the Bushveld Complex, from same sources as Fig. 1. The UG2 chromitite layer occurs in both east and west limbs in the Upper Critical Zone (C_UZ). Cr, Pt and V refer to chromitite, platinum-bearing and vanadiferous magnetite layers.

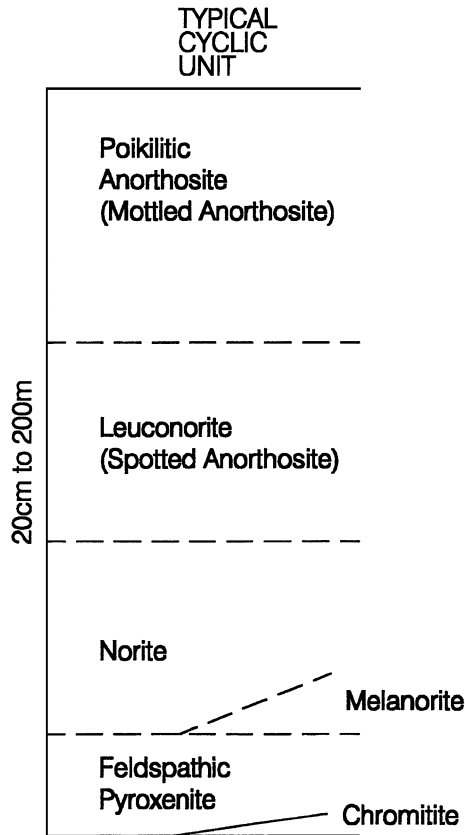


Fig. 3. Idealized succession through a cyclic unit in the Upper Critical Zone.

(Fig. 3). The chromitites cluster into three groups, Lower, Middle, and Upper (Fig. 2), and each layer is numbered from the base upward in each group. Thus, the UG2 chromitite, documented here, is the second layer from the bottom in the upper group.

3. Base of the UG2 chromitite at Karee Platinum Mine

Karee Platinum Mine is situated 20 km east of Rustenburg (Fig. 1), and both Merensky and UG2 chromitite reefs are mined for PGE (Farquhar, 1986). It is implicit from Fig. 3 that the UG2 chromitite ought to be underlain by an anorthosite at the top of the UG1 cyclic unit. However, frequently, it is underlain by a coarse-grained feldspathic pyroxenite

up to 1 m thick (Lee, 1996; Maier and Eales, 1997; Viljoen and Schurmann, 1998), which occurs above the UG1 anorthosite. At the Lonmin Platinum Mine, there are large areas where the UG2 is directly underlain by anorthosite, ranging up to 3 m thick, providing a very dramatic colour contrast at the contact (Farquhar, 1986). Underground exposures show slight irregularities from a perfectly planar contact, which can vary from minute up to large depressions 30 m across and tens of metres deep, the largest of which are called potholes. It is only possible to see a vertical section in any given mine face, and so the plan view of such irregularities is not obvious. Because of complexities of plunging reef and irregularities in the thickness of the ore body, these potholed areas are not mined, and so the details of the contact between potholed footwall and UG2 chromitite cannot be examined underground.

Open-pit mining has also been undertaken, and the contact relations between the underlying anorthosite and the UG2 may be studied. The footwall anorthosite is a hard, unfractured rock compared to the much more friable chromitite layer, and makes a good basal contact for the open pit mining. However, in general, the sloping base of the pit is covered in dust and small rock fragments. As a result of a very dramatic storm that occurred at the end of open pit mining, the floor of the entire pit was washed clean, and no subsequent mining activity occurred to dirty the floor. An area of approximately 100 m × 100 m of this cleaned floor was exposed. This event provided a unique opportunity for a detailed study of the contact relations. Numerous photographs of this washed pavement, forming the top of the anorthosite, are shown and described in detail here. For environmental and safety reasons, the pit was then infilled. This contact is parallel to general layering and dips at 11° to the north. On this surface are irregularities that occur on different scales. A general photograph of this surface is shown in Fig. 4, in which the larger pothole structures are clearly visible.

3.1. Small-scale structures

The smallest scale of irregularities can be recognized by the presence of small (± 2 cm) black, chromite spots on the white anorthosite. (Fig. 5). The contact between the anorthosite and chromitite breaks easily and the UG2 is easily mined out. However,



Fig. 4. General view of part of the open pit (about 60 m × 40 m), looking south. The sequence dips to the north. The larger potholes are clearly visible. Note the partial overlapping or coalescence to two shallow potholes in the bottom right to the centre of the photograph. The irregular distribution and variable depth to width of the potholes are visible. The dark rock on the steep left face is the pyroxenite overlying the UG2 chromitite.

where there are slight depressions, the basal few grains of chromite adhere to the anorthosite (Fig. 6) and are not removed by mining. These few grains of chromite do not reach the lip of the dimple, and so the black spots shown in Fig. 5 are slightly smaller than

the size of the actual depression. The diameter of these depressions was measured by placing a ruler across the planar surface. Typically, they are about 3 cm in diameter with little variation. Their depth is also very uniform, being about 5 mm deep. These depressions



Fig. 5. Photograph of the small-scale dimples in the anorthosite surface. The edge of an intermediate-size depression is seen to the bottom right, and has only one small dimple. Small patches of loose chromite-rich gravel occur in the top left and bottom right.

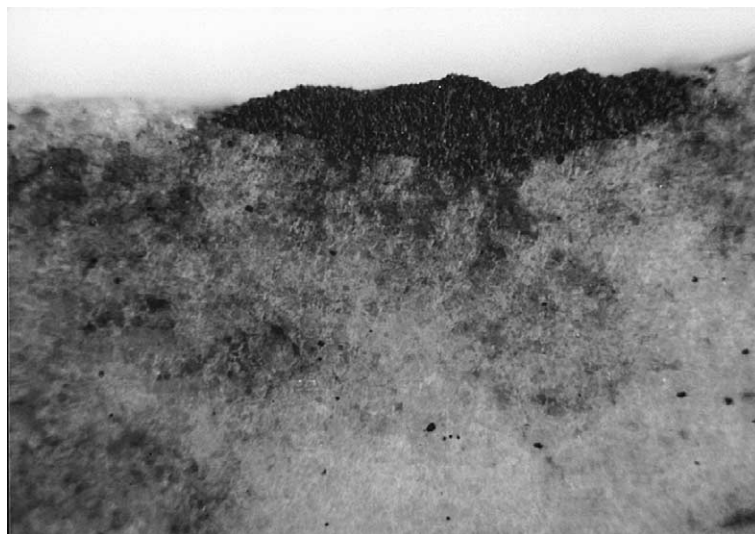


Fig. 6. Photograph of vertical section through a small dimple. Disseminated chromite and large orthopyroxene oikocrysts are visible in the footwall anorthosite. Horizontal field of view is 50 mm.

are typically spaced 5–10 cm apart. By placing a straight edge over several of these depressions, it was observed that the surface between the depressions was flat. Given an average diameter of 3 cm and a spacing of 7 cm, the depressions occupy about 20% of the surface area. No attempt has been made to measure the frequency distribution of these depressions over

several areas of the pit, but the overall impression is that this distribution density is fairly uniform over the entire pavement (with exceptions described below). No obvious pattern has been identified in their distribution, but occasionally there may be a slight preferred orientation and elongation of these depressions in a down-dip direction (Fig. 7).



Fig. 7. Slight elongation and preferred orientation pointing down-dip (towards bottom of photograph) of small-scale depressions. Patches of loose chromite-rich gravel occur at top right and bottom left.

3.2. Intermediate-scale structures

Intermediate size depressions are distributed among the smaller structures (Fig. 8). Too few of these intermediate-sized features exist to conclude whether there was a regular or preferred distribution. These depressions are about 40 cm across and vary, but can be up to 40 cm deep. Thus they have a greater depth-to-width ratio (but still less than unity) than the small-scale depressions. They are generally circular. For a few centimeters around the periphery of these intermediate-scale structures, the small-scale structures may be absent or scarce (Fig. 5). We emphasize that there does not appear to be a continuum of size distribution between the small-size (3 cm) and the intermediate-size (40 cm) depressions.

An exception to the random pattern of the small-scale structures occurs on the edge of one of these intermediate-scale depressions, where these small structures are elongated and aligned radially around the edge of an intermediate-size structure (Fig. 8).

3.3. Large-scale structures (potholes)

The large structures are potholes that have been well documented in the past (Cousins, 1969; Ver-

maak, 1976; Carr et al., 1994). However, here the shape can be clearly appreciated. The largest in the quarry is 12 m across and about 4 m deep (Fig. 4). They have a random distribution. Most are subcircular in plan (Figs. 4, 9 and 10). In one example (Fig. 4), the shape is more irregular, but is considered the result of two overlapping potholes, one much larger than the other. The coalescence of two or more potholes has also been recorded underground (Viljoen et al., 1986; Leeb-du Toit, 1986).

In cross-section, potholes are often asymmetrical (Fig. 10) — the slope on the up-dip side being greater than on the down-dip side, even allowing for the regional dip. The sides of the potholes are not always smooth. In some cases, there are corrugations on the sides that are more prominent on the up-dip side of the pothole (Figs. 9 and 10).

3.4. Comparisons with underground features

Examples of irregular basal contacts are seen underground, but as pointed out above, only as vertical sections. All would be classified as intermediate- and large-scale structures as described above. An example of an intermediate-scale structure is shown in Fig. 11. The small-scale depressions have



Fig. 8. Radial distribution and elongation of small depressions about an intermediate-sized structure (pencil at top left of intermediate sized depression gives scale). Loose chromite gravel is visible in top left.



Fig. 9. View of a typical pothole looking obliquely up-dip. The up-dip edge (on left) often displays small corrugations resulting from slight changes in dip of the erosional contact (here picked out by concentrations of loose chromite lying on flatter surfaces). Note the steepening of dip of the pothole near the bottom (seen in the sun-shaded section on right).

not been noted underground. However, it is not certain that such small undulations (less than 0.5 cm) would be noticed. They are only obvious in the quarry floor because they have a selvage of chromite grains preserved in their bases. None has vertical edges or overhanging lips that have been documented for the Merensky Reef potholes.

3.5. *Other examples of irregular basal contacts*

The features described here of the irregular basal contact are not unique, but the surface exposure provides for unique measurements and photographic recording of their shapes on a planar surface. Undulating contacts to the base of the Merensky Reef



Fig. 10. Photograph of pothole showing asymmetry in cross-section with a steepening of dip into the pothole on the up-dip (left) side, especially near base.

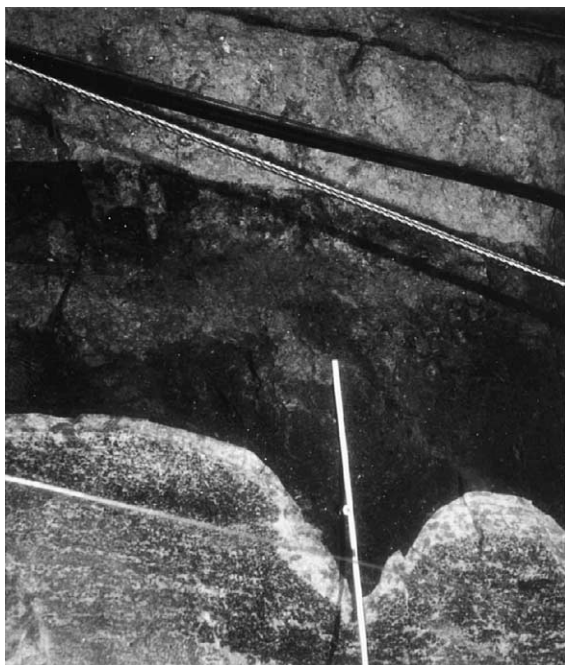


Fig. 11. Underground section through base of UG2 showing depression with depth equal to width. Ruler is 1 m long. Here the footwall is a norite, with a thin veneer of anorthosite following the irregular contact. Elsewhere the anorthosite is much thicker and may be cross-cut by the potholing process. Note that the top contact of the chromitite above the pothole is planar. It is overlain by pyroxenite that contains two thin chromitite stringers. (Apparently obliquely cross-cutting lines, sloping down to right, are cables and their shadows.)

have been reported (Vermaak, 1976) and are discussed in detail below. Cameron (1982; his Fig. 7) referred to a dimpled 3 mm chromitite layer as disconformably lying upon a pyroxenite, with an anorthosite layer above. A field photograph of this feature is shown in Fig. 12. This example demonstrates that pyroxenite footwall can also develop non-planar structures.

Below the UG3 chromitite on Maandagshoek (Gain, 1985), also in the eastern Bushveld, occur features analogous to the small structures documented here (C.A. Lee, personal communication). The small-scale depressions, usually filled with chromite, are present (Fig. 13). They are much more irregularly distributed on the anorthosite surface than in the present example, and occupy very much less than the 20% of the surface seen at Lonplats. Close to one medium-sized depression, the surface of the

anorthosite is irregularly grooved, with a slight tendency for the ridges to run radially towards the depression (Fig. 13).

4. Discussion

Here we discuss some observations and hypotheses about other examples of possibly similar structures, and debate whether such interpretations might be applicable in the present examples.

4.1. Small-scale structures

The structures documented here are restricted to the base of the UG2 chromitite layer that forms the base of a cyclic unit. Whether similar structures occur within silicate packages is uncertain. They have not been documented, but the patterns shown in Figs. 5–7 are unlikely to have been recorded without exposing a perfectly fresh bedding-parallel surface. The colour contrast makes the structures clear in the present example, but would be difficult to recognize without such strong modal layering. Thus, similar structures might exist in silicate rocks, but no appropriate exposure has been found. In the following discussion, we emphasize their occurrence at the base of a cyclic unit. If they can be shown to occur throughout the silicate succession, too, a reassessment would be needed.

4.1.1. Redissolution processes

Their occurrence at the base of cyclic units suggests that their origin may be related to the process that initiates the cycles themselves. Chromitite genesis has been linked to the concept of addition of primitive magma into, and mixing with, resident magma that produced the anorthosite in the footwall (Irvine, 1977). Campbell (1986) investigated the effect of thermochemical erosion resulting from the addition of hot magma. The process was simulated by the study of a block of ice onto which was poured warm salty water. Campbell (1986) recorded two different types of erosive processes. In general, the surface of the ice became dimpled. Melting of ice produced a solution that was less dense than the salt solution causing the melting, and so finger plumes developed. He stated that these finger plumes became

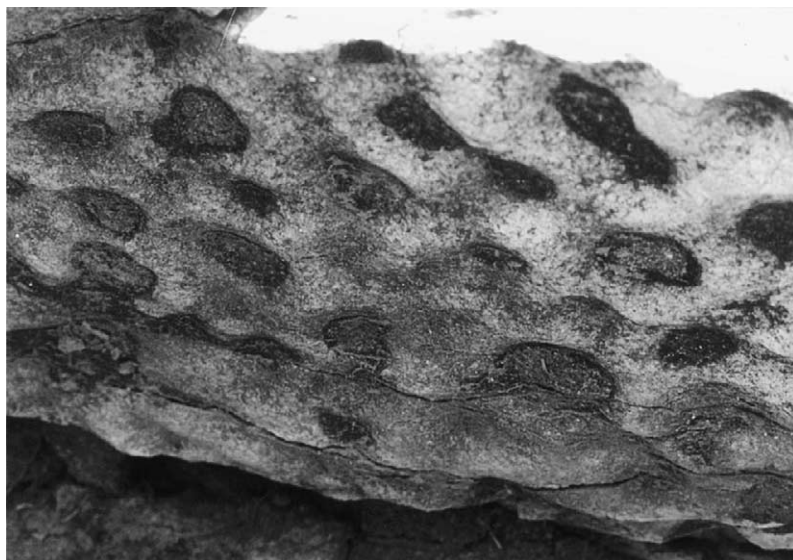


Fig. 12. Undulating MG2 chromitite overlying pyroxenite on Jadglust, eastern Bushveld Complex (see Cameron, 1982; his Fig. 7). This photograph is of the underside of an overhanging outcrop looking obliquely upward. Footwall pyroxenite is in bottom left. Undulating surface between pyroxenite and overlying anorthosite is picked out by a thin selvage of chromite. Field of view 20 cm × 30 cm.

“locked onto individual pits” as erosion proceeded such that dimpling, rather than a planar eroded surface, was produced. The fluid dynamic geometry of this process is shown in Fig. 14A, where the result of dissolution produces a low-density liquid that rises as a finger. This liquid has to be replaced by the overlying denser liquid. At the point where this dense liquid reaches the ice, it will be at its warmest and hence capable of melting ice. As it moves outward, it becomes cooled and so is less effective at melting. Thus, the cusp-shaped melting profile, shown in cross-section in Fig. 14A, results. The important geometry is that the position of the rising finger produces an upward pointing cusp on the eroding surface. Our detailed observations on the surface of the anorthosite are fundamentally different. Between each dimple, there is a flat surface (Fig. 6). To produce the topography we observe would require that the fingers had a distribution as shown in Fig. 14B, which requires a stagnant portion of magma between each pair of fingers. Cells in convecting systems do not produce such a geometrical relation. Hence, we are not convinced that this process can produce the detail of the small-scale structure we have documented.

4.1.2. *Interference ripples*

In sedimentary rocks, interference ripples can produce a pattern similar to that seen in Fig. 12. However, two details of the geometry shown in this study and for interference ripples are important in relation to the observations we have documented. First, interference ripples are constructional, not destructional, processes and have trochoidal surfaces. Second, the interference produces an “egg box” pattern, such that all the cusps and depressions tend to define a regular, rectilinear pattern. The pattern we observe on the top of the anorthosite has planar surfaces between depressions and cusps are not regularly distributed, and so do not obviously equate with interference ripple structures.

4.1.3. *Diapirism*

Chromite is much denser than plagioclase, and hence, where a layer of chromitite overlies anorthosite, there is a potential gravitational instability. If both layers still contain a proportion of interstitial liquid, the layers may have sufficient mobility that incipient diapirism could be induced. The process would produce an undulating interface that is not consistent with the alternating planar surface and dimples seen in



Fig. 13. Irregular small structural depressions below the UG3 chromitite on Maandagshoek, eastern Bushveld Complex (see Gain, 1985). The UG3 chromitite is visible on the left. The anorthosite shows an irregularly grooved surface, occasionally with thin selvages of chromitite preserved in the depressions. The grooves show a slight preference to be aligned towards the medium-sized depression on the left (in line with the point of the pencil used for scale).

the present case. The geometry shown in Fig. 12 has chromitite (and pyroxenite) underneath anorthosite, so that feature could not have been gravitationally induced.

4.1.4. Impact-generated dimpling

Vermaak (1976) noted the dimpled surface of the basal chromitite of the Merensky Reef lying on an anorthosite footwall. He suggested that the dimpling was the result of sinking of boulder-sized aggregates of coarse pyroxenite onto a floor of unconsolidated chromitite and underlying anorthosite. He further cited the example of the “boulder bed” (Lee and Sharpe, 1979) that underlies the Merensky Reef by several metres, which contains 10–20 cm sized sub-spherical bodies of pyroxenite in anorthosite, as

evidence for the existence of such aggregates. To apply that model here would require settling of chromitite bodies a few centimeters in diameter. We know of no independent evidence for the existence of such chromitite blobs, analogous to the boulder bed, but we cannot exclude such a process. Kinnaird et al. (2002) suggested that blebs (of unspecified size) of chromite grains entrained in a contaminated magma may have descended from the upper levels of the intrusion, and could have dimpled the floor. However, no deformation of fabric is noted petrographically below the sites of impact (Fig. 15). Furthermore, only 20% of the surface has been affected by these sinking blobs. The remainder of the area formed a planar surface, which would require that in the remaining areas, gentle settling of apparently single chromite grains must have occurred.

4.1.5. Gas-escape structures

Boudreau (1992) has suggested that the potholes in layered intrusions may result from degassing of volatile-saturated unconsolidated sediment (crystal mush). He documented examples from sea-floor sediments to illustrate the process and the structures produced. The examples he documented were much larger than the small-scale features recorded here, but there is no reason why such processes could not be scaled down to the order of centimeters. Two features in this model are more consistent with this process than the remelting process. The distribution of such gas-escape structures can be completely random as observed here. Also, they may comprise only a small proportion of the total surface area of sediment. Areas between each escape feature will remain planar, representing the original depositional surface. Both features are evident here.

To investigate this process further, we have studied thin sections oriented vertically through the centre of dimples. Everywhere, the footwall anorthosite has a strong planar fabric with the long axes of grains of plagioclase lying parallel to layering (Fig. 15). This same fabric is present in sections taken below the planar contact as well. Gas or residual liquid streaming through an unconsolidated crystal mush could have caused some re-orientation or disruption of the fabric of the crystals. Beneath the dimples of chromitite, we see preservation of this planar fabric, with no suggestion of a rotation of the plagioclase

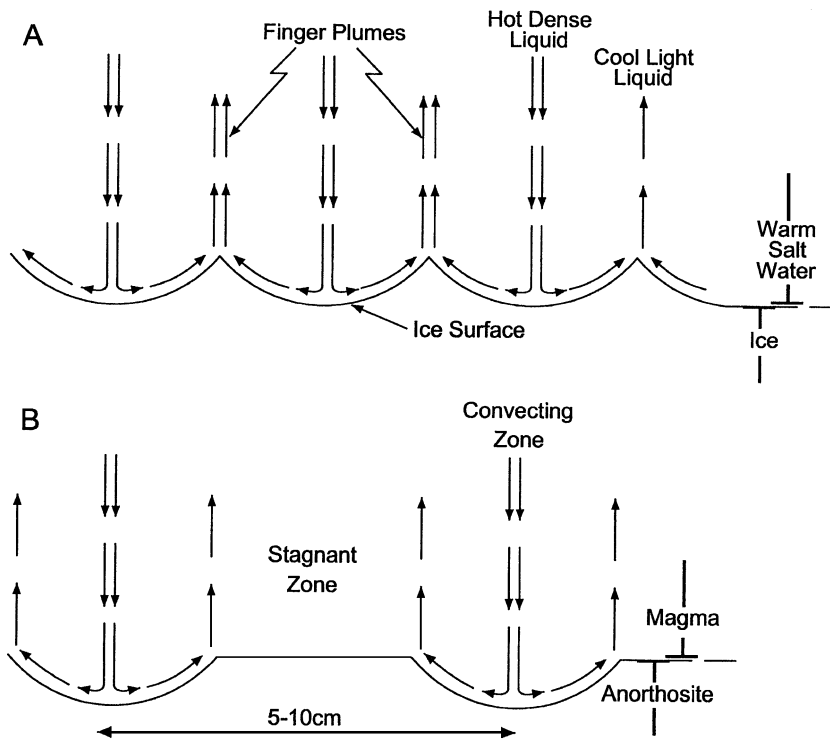


Fig. 14. (A) Reproduction of the figure by Campbell (1986) demonstrating how a dimpled surface could arise by thermochemical remelting. In order to produce the flat-topped areas between dimples, which we observed, a geometrical relation for the finger plumes and convection cells would have to be of the form shown in (B), which we believe is not realistic.

grains due to upward flow of fluid or residual liquid (Fig. 15). We also studied the distribution of interstitial pyroxene oikocrysts in the anorthosites immediately below the UG2 layer and noted no preferred concentration near to the dimples (Fig. 6).

4.2. Intermediate-scale structures

Campbell (1986) pointed out that pothole formation by dissolution by added magma would be aided if there was a pre-existing defect and suggested that



Fig. 15. Photomicrograph of anorthosite immediately below a dimple filled with chromite grains and interstitial plagioclase, showing the planar alignment of plagioclase grains. Field of view 4 cm × 2 cm.

prior existence of gas bubbles or fumaroles could represent such features that might aid downward penetration of magma, enhancing pothole development. In such cases, the mechanism might be a combination of the process driven by gas escape and thermochemical erosion discussed above. It is difficult to identify any definitive features of these intermediate structures that could support or refute the application of such processes.

There is one feature of the intermediate structures that may be of significance, although its genesis is not resolved here. Around one such structure, the small-scale structures develop a radial distribution and are slightly elongated in the same direction (Fig. 8). The appearance of this radial structure could suggest either egress or ingress of a dense liquid or slurry that was flowing at the liquid–crystal mush interface. The grooved surface seen in Fig. 13 might also suggest some lateral movement of slurry focused on the intermediate sized potholes. Addition of a dense magma or slurry through the centre of such a structure that flowed radially from a pipe might have produced a scoured surface with the observed pattern of elongate dimples. Conversely, downward draining of a dense medium might also have produced a similar pattern. However, none of these structures has been shown to have a feeder or drainage pipe at its centre, filled with a rock type any different from the footwall anorthosite.

The presence of discordant bodies cutting through potholes has been recorded by Buntin et al. (1985),

Gold et al. (1985) and Viljoen and Hieber (1986). However, in all instances, the ultramafic body was seen to cut through the rocks immediately overlying the potholed structure and hence postdated rather than initiated or caused the pothole structure. Identical discordant bodies also cut unpotholed sections of reef, and so are not confined to potholes. The most detailed petrological study of such discordant bodies was by Carr et al. (1999). They documented discordant anorthosite and pyroxenite bodies at the base of potholes (Fig. 16). They showed that the anorthosite was an upward displacement structure that postdated the infilling of the pothole. In contrast, the pyroxenite was thought to be synchronous with the pothole formation, but importantly had penetrated downward, as a Neptunian dyke, into tensional shears related to listric faulting and slumping. Thus the evidence for upward emplacement of material related to pothole formation is minimal. Furthermore, gas- or volatile-rich fluid escaping from unconsolidated sediment would have a lower density than the supernatant magma and so would rise vertically. It would not produce this pattern around the edges.

We also noted that the small-scale dimples are usually absent in the immediate vicinity of an intermediate size depression (Fig. 5), where the planar surface with the small dimples begins to gently descend into the intermediate size depressions. This could suggest that the small-scale structures were formed first. Then the process that produced the intermediate structures obliterated such irregu-

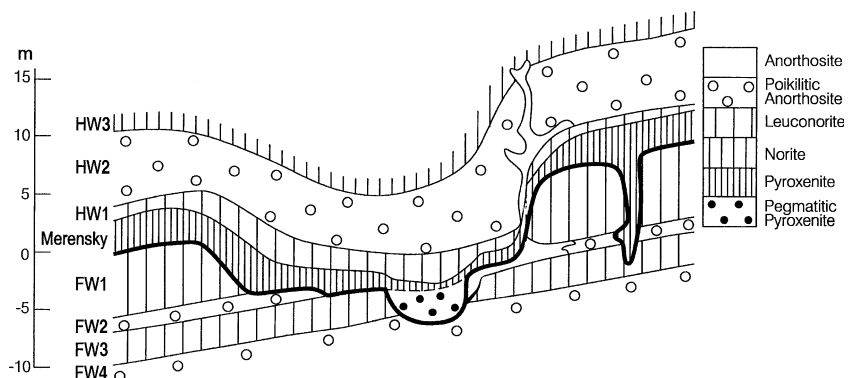


Fig. 16. Diagram from Carr et al. (1999) showing upward emplacement of anorthosite and downward intrusion of pyroxenite near the edge of a pothole. Base of pothole is identified by thick line.

larities as the deeper structures were generated. Thus, there could have been a time sequence for the different sizes of depressions, rather than all being synchronous.

4.3. Potholes

Campbell (1986) argued that defects in the footwall to potholes could aid thermochemical erosion. Where potholes reach many tens to hundreds of metres in diameter, it is difficult to envisage such large areas as being the sites of volatile escape or of thermal erosion. Campbell (1986) also noted a different control on erosion in his experiments of salt water poured on top of the ice. He recognised a number “of elongated U-shaped troughs formed over fractures in the ice, which were induced by thermal shock.” Carr et al. (1994) developed this concept further and argued that loading by a large volume of magma onto an unconsolidated magma chamber floor could have caused sagging or sudden downward collapse of the floor. They noted that such processes have been recognized during the filling of dams. Small earthquakes and subsidence of the dam floor are frequently recorded. Carr et al. (1994) argued that such a process in a magma chamber might produce elongate scars where listric faulting and down-dip slumping of unconsolidated crystal mush had occurred. Focused thermochemical erosion along the line of such scars could then have produced the potholes now observed. In support of this process, they showed a tendency for alignment of potholes along zones parallel to strike. The present exposure provides an opportunity to further examine this model. Inspection of the strike-parallel direction on either side of potholes did not reveal any features that might be consistent with the existence of a fossil scar. Nothing resembling the U-shaped troughs documented in the ice by Campbell (1986) was observed, nor was there an obvious increase in the number of small-scale structures in zones parallel to the strike direction on either side of a pothole.

The steeper angle of discordance between the pothole and the underlying layers on the up-dip side of the pothole does not constrain hypotheses. Boudreau (1992) argues that such a relation would pertain in pock marks in a gently dipping sedimentary succession, whereas Carr et al. (1994) argued that this feature results from down-dip slumping.

5. Summary

Open pit mining has been undertaken on the UG2 chromitite layer in the Bushveld Complex. The immediate footwall over part of the Lonmin Platinum Mine properties is an anorthosite that provides a spectacular colour contrast with the overlying chromitite. Features on the basal contact, not previously documented, were well exposed. Specifically, small (3 cm diameter) depressions (5 mm deep), covering about 20% of the surface, were observed because a few grains of chromite were preserved on the depressed surface. There were also larger structures, typical of potholes, but the geometry can be appreciated far more clearly than has been possible in underground sections. The pit has been subsequently infilled, and so the photographs are presented here as a record of these distinctive structures.

Various hypotheses have been proposed for the origin of depressions, especially in relation to the potholes of the Merensky Reef, but none of these ideas is totally compatible with the observations made on these small-scale depressions, and their origin remains enigmatic.

Acknowledgments

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