EVOLVING STRAIN PATTERNS DURING IMPACT IN THE WORLD'S LARGEST CENTRAL UPLIFT – EVIDENCE FOR DECLINING STRAIN RATE AND STRAIN LOCALISATION WITHIN MINUTES

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The formation of central uplifts in complex impact craters remains one of the most enigmatic aspects of cratering mechanics. Numerical modelling is able to explain the gross evolving strain patterns within central uplifts but, as yet, cannot resolve the smaller scale patterns responsible for structures at the outcrop scale or in heterogeneous targets layered at scales up to tens to hundreds of metres.

The Vredefort Dome is the 90 km wide, deeply exhumed (~10 km of erosion [1]), central uplift of one of the world's largest complex impact structures (D ~320 km [1]). The dome comprises a 40-km-wide crystalline basement core that is surrounded by a 25 km wide collar of layered supracrustal and intrusive rocks that show complex macroscopic deformation features. The dome presents a unique opportunity to study impact-related deformation in the deep levels of a giant impact structure that may be inaccessible below younger impact structures. The layered metasedimentary rocks of the Witwatersrand Supergroup in the collar, in particular, provide planar markers on scales ranging from millimeters to hundreds of meters. This allows for elucidation of fault displacemnets, kinematics, block rotations and fold patterns, as well as strain patterns.

This study examines the geometry and sequence of formation of complex structural deformation features induced by the impact in a quartzite-metapelite-ironstone succession located at a radial distance of ~22 km from the centre of the dome in the northwestern collar. The following sequence of impact-related strain features have been identified: (1) A pair of pervasive, mm- to cm-spaced, orthogonal "shatter cleavages" [2]. The shatter cleavages are attributed to passage of the shock wave. Restoration of the strata to the time of impact (horizontal orientation) produces an intersection lineation that can be projected to the point of impact (located ~10 km above the centre of the dome); (2) Horsetail fractures, branching off a preferred shatter cleavage are shown to terminate in the direction of shock wave propagation; (3) Shatter cones, restoration of the master shatter cone axis, to the time of impact, produces an lineation that can be projected to the point of impact; (4) Polyphase folding: F1 folds have upright axial planes, trending oblique to the strike of the collar, with moderately inwardly plunging hinges, ~100 m wavelengths and decametre amplitudes, showing no vergence; F2 folds are on a scale of hundreds of metres and comprise of overturned, centrifugally-verging folds, with moderately steeply centripetally-dipping axial planes and horizontal tangential hinges. F2 fold hinges are commonly cut by thrust faults; (5) A network of pseudotachylite-bearing faults with oblique- to normal-slip displacements of up to a few tens of metres that are oriented oblique to the strike of the collar and show some preferred orientation parallel to the F1 folds, and ; (6) Extensional faults, that cross-cut pseudotachylite veins.

After palinpastic restoration, these deformational features can be classified into 4 main phases:
1) Shock Deformation — shatter cleavages, horsetail fractures, and shatter cones forming during the contact and compression phase.
2) Ductile Deformation — F1 radially-trending, centripetally-plunging folds, associated withconstrictional during the early phases of the modification stage - central peak formation.
3) Brittle-Ductile Deformation — F2 folds, associated with radial and tangential extension during the mid-modification phase - central peak collapse.
4) Brittle Deformation — faulting and frictional melting with associated pseudotachylite emplacement, and extensional faulting that post dates pseudotachylite emplacement. Late modification phase - central peak collapse and stabilisation.

These results suggest that detailed structural mapping of layered target rocks in central uplifts can help discriminate between different strain patterns associated with various stages in the formation of central uplifts. The results indicate that at depth vertical movements associated with uplift and collapse are more significant, as opposed to near surface features that preserve more significant lateral displacements.

References:

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