BUSHVELD IGNEOUS COMPLEX, SOUTH AFRICA: ABSENCE OF SHOCK-METAMORPHIC EFFECTS AFTER AN EXTENSIVE SEARCH. Bevan M. French, Planetary Materials Program, Code EL-4, NASA Headquarters, Washington, DC 20546.

During 1981-1982 an extensive search was made for shock-metamorphic features in the Bushveld Igneous Complex (BIC) of South Africa in order to test the theory that this large structure had formed by meteorite impact. Sampling concentrated on pre-Bushveld quartzites which underlie the BIC and are also found as inclusions in the Rooiberg Felsite, a possible impact melt unit. No megascopic features (shatter cones, pseudotachylite breccias, etc.) were found in outcrop. More than 300 quartzite samples were examined petrographically; no microscopic shock effects were found. The results suggest that the BIC is entirely internal in origin and is not related to meteorite impact.

The BIC is a classic structure because of its size, complexity, and economic importance (1-3). The BIC forms a multiple-lobed basin that extends more than 450 km E-W and 250 km N-S and covers approximately 67,000 km^2. The rocks consist of a lower layered mafic series about 7.5 km thick overlain by an upper "epicrustal" series of granites and felsites about 4.5 km thick. The BIC was emplaced about 2000 m.y. ago into older sediments of the Transvaal System.

Serious consideration of the BIC as a possible impact structure has resulted from the growing recognition of meteorite impact as a significant geological process on the Earth (4-7). Early proposals for an impact origin were based on the close geographic association between the BIC and the Vredefort impact structure (8) and on similarities between the BIC and Sudbury, an established impact-volcanic structure (9-11). Rhodes (12) developed a detailed history in which the BIC was produced by a simultaneous triple impact. In his scheme, the presently observed large inliers of pre-Bushveld rocks represent central uplifts, while the lower part of the Rooiberg Felsite is an impact melt.

A preliminary examination of a restricted sample suite from the BIC (13) failed to discover any shock-metamorphic effects. In this study, more extensive sampling was carried out, concentrating on the older rocks immediately below the Rooiberg Felsite and on quartzite inclusions in the Felsite itself.

Rooiberg Felsite. This unit of massive acid volcanic rocks overlies the granites and layered mafic rocks of the main BIC. The Rooiberg may be as much as 3-4 km thick (14-17) and may have had an original volume of about 200,000 km^3, or approximately that estimated for the Columbia River Basalts. Most of the Rooiberg consists of dense thick lava flows with a variety of textures: microporphyritic, spherulitic, vitrophyric, and microgranophyric. Pyroclastic units are only occasionally present; they consist of agglomerates (with quartzite inclusions) and rare ash-flow tuffs. Recent work has shown that the lower Rooiberg is not entirely massive felsite and that lavas are interbedded throughout the entire section with subordinate pyroclastics and sediments (18,19).

Quartzite Inclusions. Quartzite xenoliths, derived from underlying pre-Bushveld metasediments, are occasionally abundant in the Rooiberg Felsite at various locations and horizons; individual inclusions range in size from a few cm to more than 150 m. Their lithologies are ideal for developing and preserving shock lamellae in quartz. Virtually all inclusions are medium- to coarse-grained orthoquartzites which display a variety of metamorphic textures but show little or no alteration by the Felsite itself. More than 225 separate inclusions, collected from several areas as much as 150 km

apart, were examined petrographically for shock lamellae and other shock effects. No shock lamellae were found. The quartzites are, in fact, surprisingly undeformed. Cataclastic textures are rare, and individual quartz grains show only ordinary metamorphic deformation lamellae and single or multiple trails of fluid inclusions. These normal features are quite distinct from impact-produced shock lamellae.

Basement Rocks. In two areas (Rooiberg and Marble Hall) the Rooiberg Felsite rests directly on pre-Bushveld quartzites and other sediments, forming a contact suggested to be the floor of the original impact structure (12). No shatter cones or pseudotachylite were observed in outcrop in these areas. About 80 quartzite samples, collected at distances ranging from less than 1 m to 500 m from the contact, also show no shock effects, only normal metamorphic deformation lamellae and fluid inclusion trails.

The apparent absence of shock effects in a large and diverse suite of suitable samples indicates that the BIC is not an impact structure. This conclusion agrees with: (1) the apparent lack of shatter cones and pseudotachylite, and (2) the absence of any units resembling fallback breccias in the Rooiberg sequence. There now seems to be no genetic connection between the BIC and the nearby Vredefort impact structure, at which shock-metamorphic effects are well developed. Large terrestrial igneous structures can apparently form without external meteorite impact, and the Sudbury structure remains as the only known example of a composite impact/igneous structure.

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(1) Willemse, J. (1969), Econ. Geol. Mon. 4, 1-22.
(2) Visser, D.J.L. and G. von Gruenewaldt (eds.) (1970), Geol. Soc. S. Africa Spec. Publ. 1, 763 p.
(3) Hunter, D.R. (1976), Econ. Geol. 71, 229-248.
(4) French, B.M. and N.M. Short (eds.) (1968), Shock metamorphism of natural materials, Baltimore MD, Mono Book Corp., 644 p.
(5) Dence, M.R. (1972), Rept. 24th Intl. Geol. Congr., sect. 15, 77-89.
(6) Grieve, R.A.F. and P.B. Robertson (1979), Icarus 38, 212-229.
(7) Grieve, R.A.F. and M.R. Dence (1979), Icarus 38, 230-242.
(8) Dietz, R.S. (1962), J. Geol. 70, 502-504.
(9) French, B.M. (1968), Ref. (4), 383-412.
(10) French, B.M. (1970), Bull. volcanol. 34, 466-517.
(11) Hamilton, W. (1970), Ref. (2), 367-379.
(12) Rhodes, R. (1975), Geology 3, 549-554.
(13) French, B.M. and R.B. Hargraves (1971), J. Geol. 79, 616-620.
(14) von Gruenewaldt, G. (1968), Trans. Geol. Soc. S. Africa 71, 153-172.
(15) von Gruenewaldt, G. (1972), Trans. Geol. Soc. S. Africa 75, 121-129.
(16) Rhodes, R. and M.D. DuPlessis (1976), Trans. Geol. Soc. S. Africa 79, 183-185.
(17) Coetzee, G.L. (1970), Ref. (2), 312-325.
(18) Clubley-Armstrong, A.R. (1977), unpubl. M.Sc. thesis, Dept. of Geology, Univ. of Pretoria, 107 p.
(19) Clubley-Armstrong, A.R. (1980), Annals Geol. Surv. S. Africa 14, 11-18.