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M. E. ZEIN ELDINE
A. A. ZAKY
R. HAWLEY
M. C. CULLINGFORD

Corona Group,
C. A. Parsons and Co., Ltd.,
Newcastle upon Tyne, 6.

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Rheological Characterization and Incompressible Flow

In the published literature it is sometimes stated that a knowledge of two normal stress differences as a function of shear rate together with the viscosity shear rate relation and the condition of incompressibility is sufficient to characterize non-linear viscoelastic flow because the condition of constant volume gives another relationship between normal stresses.

Consider the stresses to be divided up in the following way:

$$\tau_{ij}' = \tau_{ij} - p\delta_{ij} \quad (i, j = 1, 2, 3)$$

where p is an arbitrary hydrostatic pressure and δ_{ij} is the Kronecker δ ,

$$\delta_{ij} = 0 \text{ if } i \neq j \\ = 1 \text{ if } i = j$$

If, for example, we consider a material in simple shearing motion $(u_1, 0, 0)$, where $u_1 = kx_2$ in the co-ordinate system (x_1, x_2, x_3) and the normal stresses are $(\tau_{11}, 0, 0)$, which is a definite possibility. The constant volume condition for zero p is:

$$\tau_{ii} = 0 \quad \text{liquid}$$

but this violates the assumption about the stress distribution and does not apply.

In some work the stress is divided up in the following way:

$$\tau'_{ij} = \tau''_{ij} - \frac{1}{3} \tau_{kk} \delta_{ij}$$

and $\tau''_{ii} = 0$ by definition, but this does not give additional physical information as is sometimes supposed.

In view of the foregoing no less than three functions of the normal stresses are required in general plus the viscosity-shear rate relation if volume changes are ignored. But the volumetric strain gives a further relation between the normal stresses.

J. HARRIS

Department of Civil and Mechanical Engineering,
Queen's College, Dundee.

GEOLOGY

Occurrence of Karroo System Sediments in Ethiopia

I WISH to comment on Dr. P. A. Mohr's recent communication¹, "Occurrence of Karroo System Sediments in Ethiopia".

Two of Mohr's conclusions are extremely far-reaching from a palaeogeographic point of view in that the Karroo 'System', essentially a southern African group of formations, is extended well north of the equator into north-east Africa. However, before the following conclusions are accepted by African stratigraphers, they must be supported by more evidence to prove that: (1) the pre-Adigrat sediments recently discovered resting on the

Basement Complex in the Blue Nile (Abbai) Canyon in Central Ethiopia are Permo-Triassic in age; (2) the newly discovered sediments are of Karroo type.

Essentially what Mohr and Jepsen have found is a group of sediments of pre-Adigrat age which were deposited in valleys cut in the Basement Complex, which itself had been planated in pre-Adigrat times. In my opinion all that can be said at present about these sediments in terms of international chronology is that they are post-Basement Complex and pre-Bajocian in age.

In the absence of fossils, and no palaeontological evidence for the pre-Adigrat beds is given in the communication, is it reasonable to assume that: (1) the pre-Adigrat beds are Permo-Triassic in age; and (2) the surface on which the Adigrat formation was laid down was formed in Late Palaeozoic time?

The sub-Adigrat regional surface could equally well be much older than Late Palaeozoic, and lithological similarity is not proof of age, especially when the deposits are correlated with the Duruma formation which at its nearest point is about 900 miles away.

Also it should not be forgotten that the type area of the Karroo 'System' is in Cape Province, Orange Free State, and Natal where the composite section is more than 35,000 ft. thick; that the Karroo ranges in age from Carboniferous to Lower Jurassic; and that it consists of a great variety of rocks including tillites, volcanics and most common types of sediments.

Therefore, to suggest that pre-Adigrat "thin bedded bluish-grey calcareous mudstones overlain by massive dark grey sandstone beds" are of Karroo type, and in addition are Permo-Triassic in age, is unjustifiable in my opinion.

Clearly, then, before a Karroo label, as the title of the letter implies, is attached to the Blue Nile pre-Adigrat sediments, and before epeirogenic movements and erosional cycles of regional significance are dated, palaeontological evidence must be provided to date these events.

A. J. WHITEMAN

Department of Geology,
University of Khartoum,
Khartoum, Sudan.

¹ *Nature*, **199**, 1086 (1963).

To ascribe the pre-Adigrat beds of the Abbai basin to the Karroo System has so far been based, within the limits of certainty given in my first communication on denudational chronology, lithology, and relationship to the Mesozoic marine horizons. Intended micro-palaeontological and isotopic age-determination work on these beds should further clarify their stratigraphical position.

The end-Palaeozoic age of the termination of neoplenation of the Basement rocks in northern, central and eastern Ethiopia has been accepted by most previous workers^{1,2}, and Prof. Whiteman presents no evidence to support the doubts he now casts on this dating.

Prof. Whiteman considers that the immediately evident disparity between the type Karroo System rocks and the pre-Adigrat sediments, in terms of thickness, variety of lithology, and spatial separation, is such that suggestion of a correlation of the latter with the Duruma formation of coastal Kenya is unjustifiable. In this respect it is interesting to note, for example, the recent attribution³ to the Karroo System of such distant and minor sedimentary outcrops as the Ecca-type shales of Uganda and the Mansa Guda clastics of northern Kenya. While intimacy of spatio-temporal features of sediments is important in making correlations, it is not critical.

P. A. MOHR

Haile Selassie I University,
Addis Ababa, Ethiopia.

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² Mohr, P. A., *Geology of Ethiopia* (Addis Ababa, 1962).

³ Saggerson, E. P., *The Physiography and Geology of East Africa* (Hawkins, Ltd., Nairobi, 1962).