

## **Structures in Peninsular Malaysia and their interpretations<sup>1</sup>**

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*So general has been the acceptance of the hypothesis that it has acquired a curious air of finality. It seem to have escaped the ordeal of criticism to which every scientific hypothesis should be subjected, not only by the skeptics but also by those who believe in its probable truth.....Lawson, 1914.*

*It is a common failing with geologists that at the conclusion of an endeavor based on data assiduously gathered and assessed, they permit themselves to indulge in ill-founded prognostications, half-true generalizations and even virtual fantasy.....Burton, 1970.*

The privilege accorded to a retiring President to air his views freely without having to be subjected to the ordeal of criticism in a way imposes a constrain on the nature of the address. It is tempting to propose a new and revolutionary geological concept but as rightly pointed out by Lawson in the above quotation, every new scientific hypothesis needs to be subjected to the ordeal of criticism. The second quotation which I have chosen from a well known figure in Malaysian geology, who readily admits that he is not entirely free from blame in this connection, serves to illustrate the importance of subjecting geological interpretations to close scrutiny before its acceptance. It is the purpose of this address to review in this light some of the more important structural features in Peninsular Malaysia and the interpretations and tectonic hypotheses attributed to these structures. It is not the intention to be critical of previous contributions and ideas advanced by many geologists whose important contributions to our knowledge of Malaysian geology is fully recognised. This address is devoted to presenting different view-points from those which appeared to have been generally accepted. The discussion will focus mainly on structure, deformation, orogeny and granite emplacement.

It has often been said that a good geologist must be imaginative and the advancement of geological thinking over the past few decades have owed much to the fantasies and intuitive hypotheses advanced well before sufficient geological data became available. When such data have lent support to these interpretations the greatness of the originators of important geological concepts is only then fully recognised. The history of geological sciences is filled with stories of men whose original ideas are subjected to criticism and even contempt before they are accepted by the skeptics. One of the features with Malaysian geological literature is the relatively calm acceptance or silence which meets many of the speculations advanced on important aspects of Malaysian geology. Only rarely do we encounter debate or

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criticism. One wonders if this is due to the fact that a remarkable high percentage of the geological hypotheses proposed are completely justified or could it be that the personalities of the originators of these ideas have overawed all likely opposition. One good example of this polite silence which greets even the most outlandish idea is the hypothesis by van Bemmelen (1949) on the nappe structure in Peninsular Malaysia and Sumatra. Opposition to this idea, which was suggested before the advances in the stratigraphy and structure in the peninsula made it untenable, was very low keyed and as a result, we still see this model being promoted in geological text books, for example the model by Spencer (1969), as the generally accepted one for the tectonics of this region.

Geological literature in Peninsular Malaysia is filled with many statements which claim general acceptance and if silence can be interpreted as consent, then the authors are probably justified in their claims. It is my feeling that progress in the development in geological thinking in this region needs the active participation of a large sector of the geological community. Many of the hypotheses which appear to have received general acceptance should be subjected like any scientific hypothesis to the ordeal of criticism not only by those who disagree but also by the originator whose duty to provide the evidence and argument both for and also against his own proposal should be fully recognised instead of just presenting a neat geological solution to the problem and ignoring the data which might upset this hypothesis.

Most of the evidence forming the basis for structural interpretations originate either from field work or aerial photographs and satellite imagery studies. The local tropical terrain with its generally thick soil cover and luxuriant forests greatly hinders field investigations. Only in a few scattered areas, mainly confined to coastal exposures, can the outcrops be considered to be satisfactory for detailed structural mapping. Given this limitation, it is perhaps unavoidable that most of the current ideas on the structural features in the peninsula are based on limited field observations combined with a fair degree of speculation. Interpretations based on such premises are invariably non-unique and depends to a great extent on the personal bias of the interpreter. I propose in this address to examine a few of the interpretative concepts of Peninsular Malaysian structural history with the view of illustrating other possible interpretations of the data available. If some of these alternative suggestions for the tectonic significance of the structures are deemed to be equally acceptable, then many of our concepts on the local geology need to be reappraised.

## FOLDING AND FAULTING

Folds and faults constitute the major structural elements in any deformed terrain. Although the geometry of these structures have not been well studied, much of our current ideas on the tectonics are based on these two structural features and the interpretations on their origin. Folding and faulting are interpreted as resulting from compressive stresses and together with igneous activity, metamorphism and breaks in stratigraphy, these features have been taken to provide sufficient proof of orogenic activities having taken place during several stages in the geological history of the peninsula.

The need for quantification in geology as pointed out in a previous Presidential Address (Haile, 1967) clearly applies to terms frequently used in Malaysian geology such as strongly deformed, moderately deformed and weakly deformed, which are often used to describe complete sequences from visual inspection of just one or two small exposures. Isoclinal folding is a term frequently encountered although the geometry of most of these structures with non-parallelism of the fold limbs are more appropriately described by the term tight folding or close folding rather than isoclinal folding according to the classification outlined by Fleuty (1964). Tight folding of thin competent layers cannot be taken to indicate intense compression of the whole sequence as the uniform shortening of a multi-layered sequence of varying thickness and competency can give rise to marked differences in fold styles from tight or isoclinal folds to open folds even though all the layers are subjected to the same compressive stress (Ramberg, 1964). Even in rocks which have been subjected to intense tectonic movements with contortions of the bedding to form large recumbent folds or nappes, the strain within the folded structure is extremely variable and it is not uncommon to find rocks which have undergone extensive displacement displaying very little internal distortion (Tan, 1976). The presence of folded rocks by itself may not imply the presence of compressive stresses as folding can also result from synsedimentary slumping, epeirogenic movement (Belousov, 1962, Ch. 23) and strain around diapiric intrusions (Dixon, 1975).

Our present knowledge of the folding history is far from complete. Correlation of folding events on a regional scale have not met with much success as is evident from the difficulty of extending the folding phase found in northwest Peninsular Malaysia to the rest of the country (Koopmans, 1965, Jones, 1973). It seems to be equally possible in Peninsular Malaysia that folding is largely a localised feature with different areas responding to local causes in markedly different manner. Chung & Yin (1978) by restricting themselves to the statement that in general the Palaeozoic rocks are more strongly folded than the younger rocks perhaps expressed the true extent of the serious deficiency in the known data in this field. Those who advocate or are in favour of tectonic schemes for the peninsula involving marked crustal shortening would need to find more conclusive evidence for this phenomenon than the structural evidence presently available.

Although the collection of field data on folding is hampered by the often limited and widely scattered exposures, this problem is less pronounced in the analysis of joints and faults. Several hundred measurements of fracture plane orientations can often be obtained from a single quarry or road cutting. After obtaining these data, many students of Malaysian geology have found it tempting to assume that the fractured rocks could be treated as a homogeneous body which have been fractured due to a uniformly directed stresses similar to the fractures formed under experimental conditions where a carefully selected featureless rock core is subjected to compressional stresses. No justification is offered for making this important assumption even when the field evidence indicates that the ideal conditions are unlikely to be met, for example, when the rocks show layering and folding. Following a mysterious technique which does not seem to have been well publicised, the orientations of the principal stress directions are then obtained and the deformation of the area is explained along these findings. The origin of fractures in Peninsular

Malaysia is still a subject which warrants further investigations and the usefulness of fracture orientations for the determination of stress directions needs to be carefully appraised. Even if the assumption that rocks can be treated as homogeneous before fracturing is valid, the high probability that many of the fractures present may have originated from other causes than compressional stresses cannot be ignored. The considerable evidence testifying to the importance of vertical uplift during the geological evolution of the peninsula indicates a possible tensional rather than compressional origin for at least a sizeable percentage of the fractures. The local stresses associated with the emplacement of the numerous granitic bodies are also likely to play an important role in the formation of some of the fractures.

#### GRANITE EMPLACEMENT AND THE DEVELOPMENT OF STRUCTURES

The outcrops of granites and other related intrusive rocks are so extensive that they constitute the dominant rock type over much of the country. It is therefore not surprising, that many features of Malaysian geology are attributed in one way or another to the origin, emplacement and the influence exerted by these large batholithic masses or rocks on the surrounding areas. Although there has been much speculations on the relationship between the granite and the structures both within and adjacent to the intrusive body, surprisingly little has been said of the mode of emplacement of these bodies. The mode of emplacement of large intrusive masses control to a large extent the type of structures developed both in the country rocks, and the margin and interior of the intrusive. The two types of mechanisms which are generally favoured, stopping and diapirism (Pitcher, 1978) would give rise to the development of markedly different structural features. Piece-meal stoping and cauldron subsidence would leave little imprint on the country rocks except for the margins of the intrusives which may be affected by shearing. The effects of a globular granite magma rising by diapiric action on the country rocks is as yet uncertain. Experimental modelling of diapirism (Dixon, 1975) indicates that the strain in the country rock is limited to a relatively narrow belt adjacent to the intrusive body and that the zone of highest deformation is found in the region above the diapir.

Outcrops in the vicinity of granitic margins in Peninsular Malaysia do not permit detailed studies to be carried out to elucidate the relationship between the intrusive events and its effects on the country rocks. Even in well exposed and extensively investigated areas such as the Donegal granites (Pitcher & Berger, 1972), the variation of strain caused by the intrusion of large granitic bodies is far from being fully understood. However in most of the better studied areas, the structures in the country rocks which could possibly be produced or influenced by the intrusive events is rarely claimed to extend beyond a few kilometres from the granite margins. The extensive studies on the Donegal granites have also demonstrated the difficulty of interpreting emplacement levels of granites on the basis of the structures in the granite and its envelope, as suggested by Buddington (1959). Granites which are obviously emplaced at the same level in the crust display features which could be interpreted as indicating that some of the intrusives are epizonal while others are mesozonal. In Malaysia, the limited data available on the structures within the granite and its margins renders any speculation on emplacement levels as highly tentative. The commonly held view that

granite intrusion is closely related to the folding needs to be reappraised. The practice of relying almost exclusively on granitic age determination to date orogenic events needs also to be closely examined.

### GRANITE AND OROGENY

Orogeny, as defined by Hobbs *et al.* (1976, p. 467) is a complex of deformational processes by which rocks become folded, faulted and incorporated in an extensive linear or arcuate region characterised by zones of strongly deformed rocks and, commonly, by extensive metamorphism. It is interesting to note that no mention is made of igneous activity though this is a common feature of many orogenic areas. I agree fully with the exclusion of igneous events as it has been clearly shown in many different granitic terrains that the igneous event bears very little relationship, if any, to the deformation and regional metamorphism of the rocks into which the igneous rocks are emplaced. Several extensively folded belts are quite barren of granite and where granites are found in strongly deformed terrain, the folding and metamorphism of the country rocks are usually found to be much older than the age of the granite and no close relationship is obvious either in time or space between the granitic emplacement and regional metamorphism. It is often found in detail that few structures in the country rocks can be directly related to the granite intrusion. A fuller discussion on this relationship may be found in Gabrielse & Reesor (1974), White *et al.* (1974) Batemen *et al.* (1974) and Pitcher and Berger (1972). It is also of interest to note that very large granitic batholiths can be emplaced in undeformed or weakly deformed country rocks such as in Peru (Pitcher, 1978).

The belief of many workers in Malaysian geology that a close relationship exists between granitic ages and the age of the orogenic event is clearly demonstrated by the search for a Devonian granite in Northwest Peninsular Malaysia to support the existence of a Lower Palaeozoic folding phase as postulated by Koopmans (1965). Bignell & Snelling (1977) favour a Devonian intrusive event in the northwest part of the peninsula which is interpreted to support the proposed Devonian orogeny in spite of field evidence to indicate that the granite intrudes Triassic sediments. Syntectonic relationships for the granites have been claimed for some well known intrusive bodies on the basis of some observations on scattered outcrops near the granitic margins. The Kemahang granite in Kelantan is often claimed to be syntectonic or pretectonic, for example Bignell & Snelling (1977), though field evidence (Khoo, 1980) shows that the old age attributed to the granite is untenable. The almost structureless character of many Malaysian granites favours a post-orogenic rather than a syntectonic or pretectonic origin but the association of the granites with orogenic events would first have to be shown.

Results of geochronological investigations of granites show clearly the problem of associating granitic ages with the timing of deformation events. Folding and faulting are relatively short lived phenomena perhaps not extending more than a few million years. Granitic intrusives in extensive granite terrains have yielded Rb–Sr dates which show that the emplacement events extent over a relatively long period of between 60 to 80 million years (Pitcher, 1974, Batemen & Clark, 1974). The question of cause and effect is appropriate to this problem of granite and orogenic deformation. The

generation of granitic magma could be assisted by the deformation of the crust but the magma which is generated following this tectonic event need not be responsible for a large part of the deformation seen in the country rocks. If we are to look at the ages available for Malaysian granites which range from Devonian to Cretaceous, the problem of tying together the folding event and the intrusive events into a neat geological solution is almost insurmountable. It is also difficult to envisage how large granitic masses could be emplaced in a compressive environment. Partly for this reason Pitcher (1978) argues for a epeirogenic rather than a orogenic setting for the Peruvian granites.

The geological setting in Peninsular Malaysia in my opinion also warrants that some thought be given to the problem of granite emplacement as the dimensions of the granitic bodies are fairly gigantic. Introduction of these large masses would pose considerable space problem if diapirism is accepted as at least partly responsible for the rise of the granitic magma. Uplift of several kilometres have been postulated for the granitic ranges to account for their present position where the cover sediments have been removed by erosion and the high elevation of some of the granitic ranges. It seems conceivable that this uplift, which many geologists are prepared to accept for the post intrusive events, may also have been active during the granite emplacement and may reflect some large scale crustal adjustment of the basement structure, perhaps in response to some major tectonic processes in the crust. The question that comes to mind is should we not consider carefully the whole question of orogeny or, as this has been named, the Malayan orogen. Is there a need for an orogenic event to account for the features found in Peninsular Malaysia geology or could not the structures found be explained to a large extent by epeirogenesis involving essentially up and down movement. Folding and faulting could then be the product of processes similar to those in Ramberg's (1967) centrifuge experiment without the need to incorporate large scale horizontal shortening. This different outlook on the geological history of the peninsula is, in my opinion, certainly worth considering.

#### CONCLUDING REMARKS

I hope that in this short presentation I have managed to provide some food for thought on the varied possibilities of interpreting many of the structural features present. Much of our current concepts on the geologic and tectonic evolution of this region need to be proven or if deemed necessary replaced. More data, especially field data, is essential for real progress to be made in understanding the geology of the peninsula. Field work and geological mapping should be greatly encouraged and more importance should be placed on field evidence in formulating speculative schemes so that the models proposed may at least be not completely divorced from reality. The large gap that exists between the geologist who gather the field data and those who worked out tectonic models with very little feel of the actual situation needs to be overcome so that a dialogue could be entered into between these two parties.

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