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Intrabed andalusite abundance variation as an indicator of graded beds: an example from Kuala Kemasik, Trengganu

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Abstract: Interbedded meta-argillites and meta-arenites exposed at Kuala Kemasik, Trengganu, show abundant but selective development of andalusite. Many individual beds show a characteristic distribution pattern of andalusite from rare at the base to abundant at the top. This distribution pattern is interpreted to be the result of preferential development of andalusite in the clay rich part of premetamorphic normal sedimentary graded beds. The development of andalusite porphyroblasts in the original finer part of the beds has given rise to a partial reversal of size gradation. The inferred graded beds indicate that the metasediments are right side up which is consistent with the observed small scale current bedding and load structures.

INTRODUCTION

Metasedimentary rocks of probable Upper Palaeozoic age are exposed along the coastal outcrops at Kuala Kemasik, Trengganu (Fig. 1). Andalusite (chiastolite) has developed abundantly but selectively in the metasediments, and occur either as individual crystals varying in size from less than a millimeter to about a centimeter, or as lenticular clots of varying sizes. The distribution of andalusite is not uniform; in many individual beds a regular vertical variation in its abundance can be observed. The main concern of this short communication is to discuss the significance and implications of this variation pattern.

The lithology comprises a metamorphosed (low pressure, probably regional) bedded sequence of shale, siltstone and sandstone. The individual beds are generally 5–10 cm thick, but may be up to 30 cm. Much thicker (up to about 2.5 m) quartzite beds also occur, a few of which are lenticular in shape with flat tops and convex bottoms. The beds, by and large, show uniform attitudes with southwesterly dips of about 15–25° and strike 115–140°, and probably represent a limb of a large fold.

OCCURRENCE AND VARIATION PATTERN OF ANDALUSITE

Andalusite occurs profusely in metapelites (Fig. 2) and less abundantly in micaceous quartzites. Thin streaks of andalusite may rarely be seen in typical quartzites, which is indicative of original minor clay intercalations. Besides andalusite, the metapelites and micaceous quartzites contain mainly quartz and muscovite, and minor amount of opaque oxides, tourmaline and carbonaceous matters. Also, there are some subrounded grains (cordierite?) which are completely altered to low-birefringent micaceous materials. Porphyroblasts and lenticular clots of andalusite are usually subparallel to, and are occasionally wrapped by, the schistosity. Andalusite crystals and clots are partly or completely sericitized.

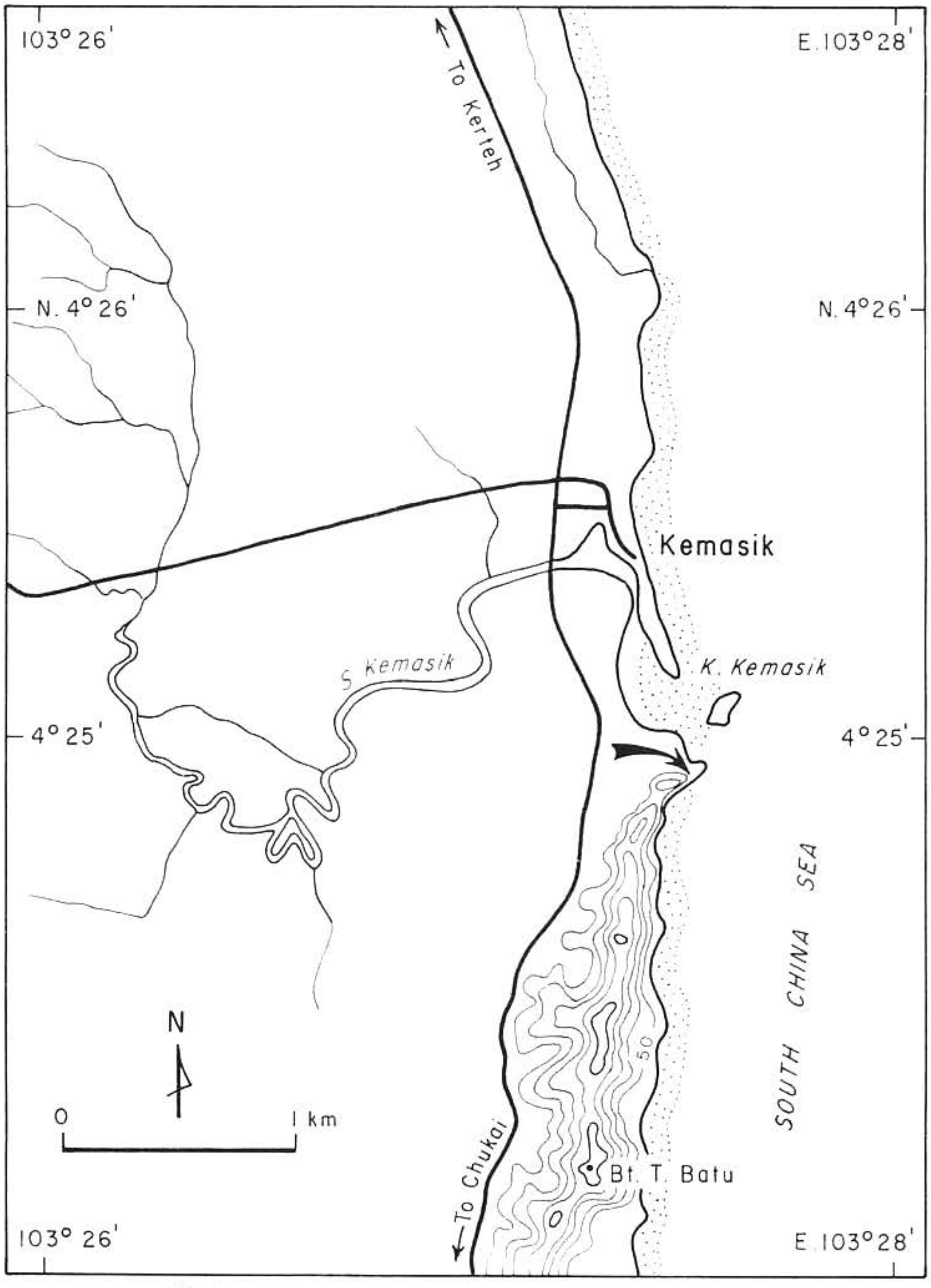

Fig. 1. Location map. Arrow head marks the exposure studied.

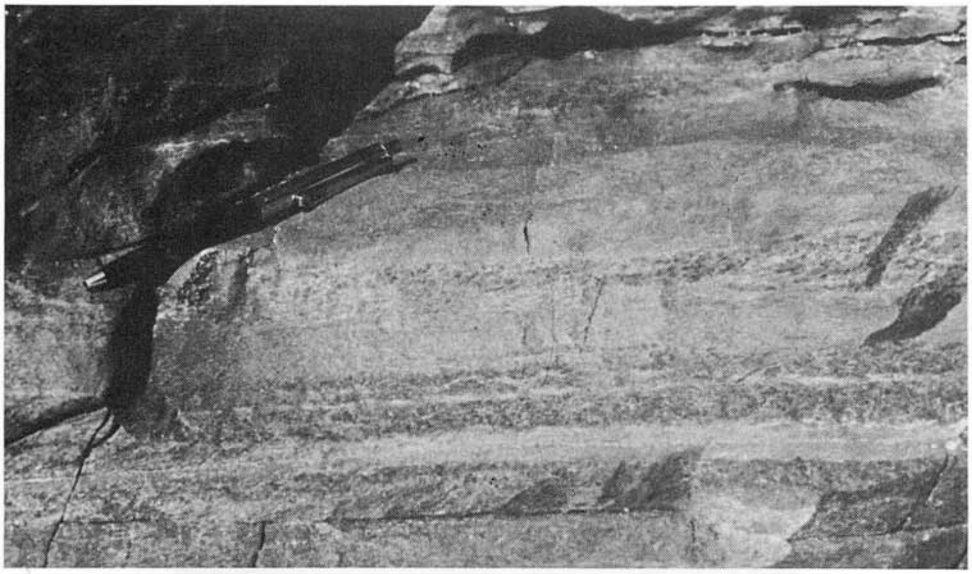

Fig. 2. Interbedded meta-arenites and meta-argillites. Note the profuse development of andalusite in the meta-argillite beds.

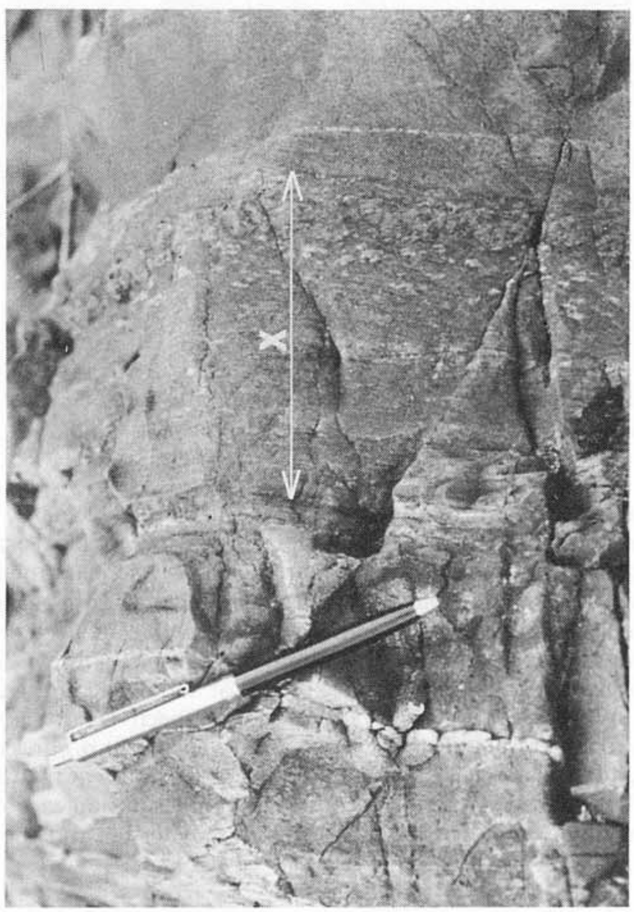

Fig. 3. Intrabed vertical variation in andalusite abundance. Systematic samples were collected from the bed marked X which is about 11 cm thick. Note the abundant coarser andalusite porphyroblasts at the top.

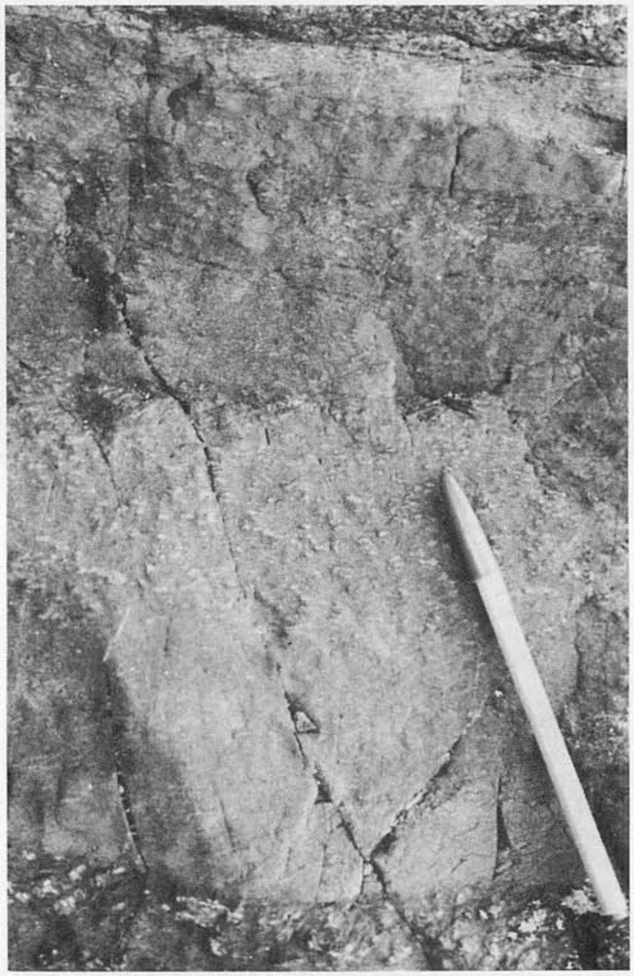

Fig. 4. Intrabed variation in andalusite distribution. Note the upward increase of andalusite in each successive bed.

A very significant feature frequently observed at Kuala Kemasik is the vertical variation in the abundance of andalusite within a single bed. Typical examples of such intrabed variation pattern are shown in Figures 3 and 4, where an upward increase of andalusite may clearly be seen. One such bed (illustrated in Fig. 3, marked X) has been examined in detail through microscopic studies of samples collected systematically from the base to the top. Representative photomicrographs of the basal, middle and upper parts of the bed, and an abundance profile of andalusite constructed from the modal values are presented in Figures 5 and 6 respectively. It is apparent that andalusite is scarcely present at the lower part of the bed, but progressively increases upwards in abundance, as well as in size, reaching a maximum at the top part. It may also be noted that the bed is quartzitic at the base, grades into micaceous quartzite in the middle, and finally becomes an andalusite-muscovite schist at the top (Fig. 5).

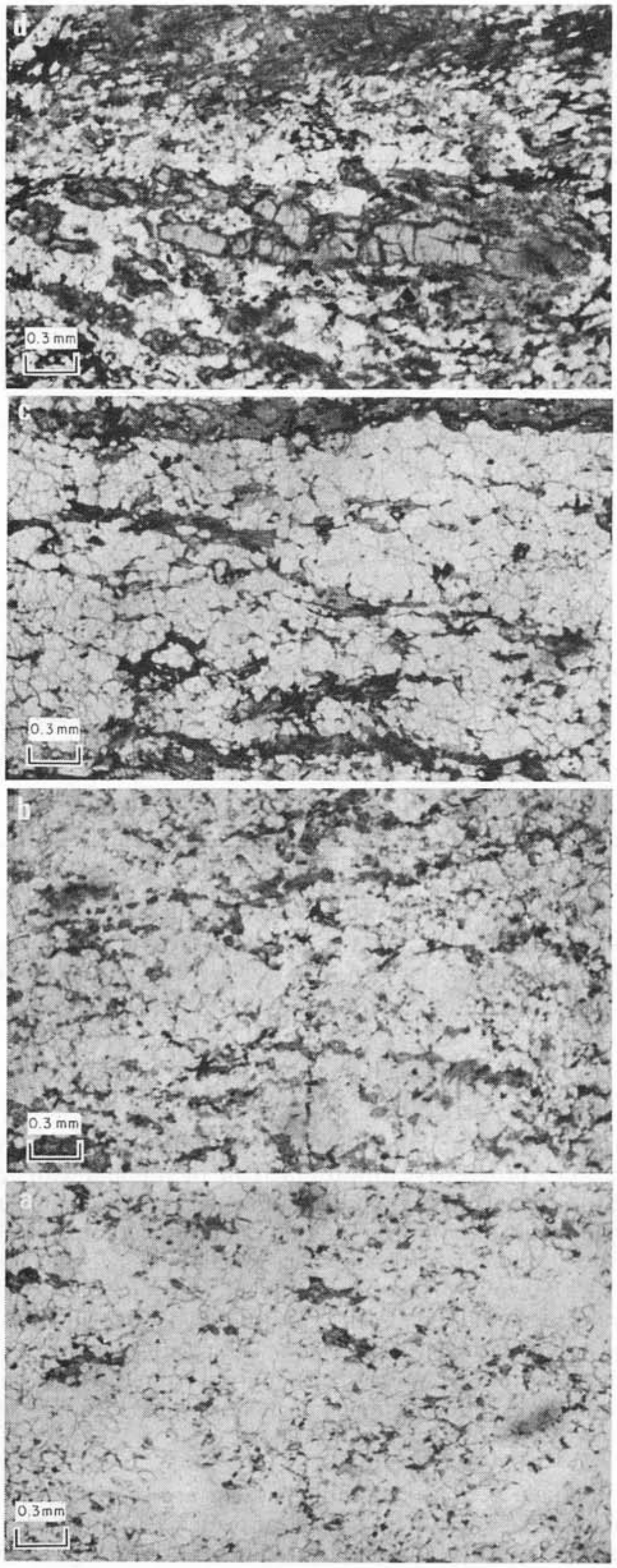

Fig. 5. Representative photomicrographs (plane polarized light) of the basal (a), middle (b, c) and upper (d) parts of the bed marked X in Fig. 3. Thin section from the top 1 cm could not be made. Note that the bed is arenaceous at the base and argillaceous at the top.

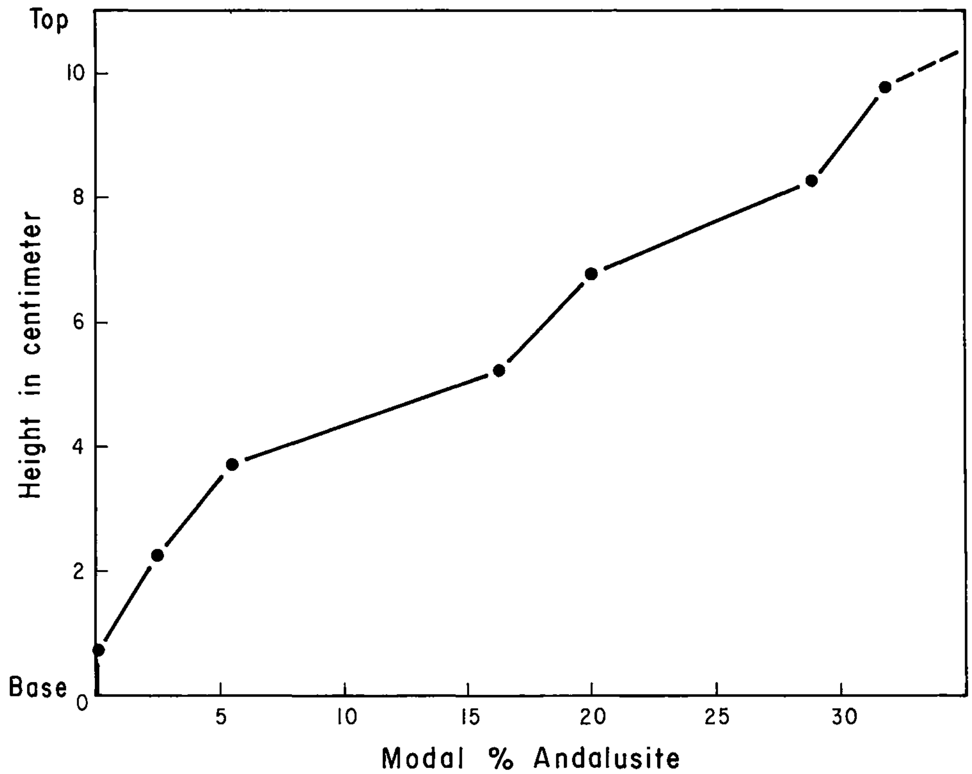

Fig. 6. Modal variation of andalusite from the base to the top of the bed shown in Fig. 3. Seven points represent modal percentages determined from seven thin sections, each covering about 1.5 cm of the bed.

INTERPRETATION AND IMPLICATIONS OF THE VARIATION PATTERN

The abundance pattern of andalusite and the overall mineralogical variation in the beds evidently reflect a progressive upward increase of alumina with decreasing silica. This may be due to either an original (premetamorphic) compositional variation in the beds or the development of compositional layering by metamorphic processes. It is known, for instance, that quartz-rich and mica-rich domains can develop in an initially homogeneous rock through selective removal or migration of silica during metamorphism and deformation (Glen, 1982: Gray, 1979). In this context, it is of particular interest to note that Shrock (1948, p. 422) cited, from Broken Hill, Australia, an example of metamorphosed graded beds inferred from the distribution pattern of garnet, which has later been reinterpreted as metamorphic layering (see Hobbs *et al.*, 1976, p. 148).

In the case of Kuala Kemasik, although there are segregations of quartz and muscovite in microscopic scale, there is no clear evidence to attribute the distribution pattern of andalusite and overall compositional variation (Fig. 5) to metamorphic layering. On the contrary, the features like well preserved bedding with sharp contacts, parallelism of andalusite-rich horizons with bedding (Figs. 3 and 4), concentration of andalusite only at the upper part of the beds. presence of small scale current bedding (Fig. 7) and load structures, provide evidence against metamorphic layering. The intrabed mineralogical variation (Fig. 5) and the abundance pattern of andalusite (Fig. 6) are not, therefore, the result of metamorphic differentiation, but bear evidence of an inherent compositional gradient. Since an upward increase of alumina would imply a similar increase of clay, it can be inferred that these beds were originally normally graded with upward fining. The occurrence of relatively coarser andalusite porphyroblasts in the originally clay-rich finer parts of the beds, however, has given rise to an apparent reversal of grain size.

The development of aluminous minerals such as andalusite in the clayey finer parts of the graded beds with apparent reversal of size grading due to metamorphism, as observed at Kuala Kemasik, are not unique. Several such examples from various localities have been described by others (e.g. Shrock, 1948). Preferential development of metamorphic minerals commensurate with the inherent compositional variation of the graded beds has important implications pertaining to the recrystallization phenomena, as it is imperative that metamorphism has, by and large, been isochemical within the limit of the bed. The apparent reversal of size grading is generally attributed to higher reaction rate in the upper part because of finer particle size. However, a complete size reversal is unlikely as metamorphic grain growth depends on a number of factors. In the Kemasik examples, for instance, only the andalusite crystals have grown to a larger size, but quartz and muscovite do not show any size gradation across the bed. Size reversal is thus only partial.

DISCUSSION

The andalusite distribution pattern and other related features described here have not hitherto been reported, to the best of our knowledge, from elsewhere in this region. In multiply deformed metasedimentary terrains like the eastern coastal belt of Malaya Peninsula, these features, if observed, may serve as an useful top-bottom criterion to provide valuable insight into structural and stratigraphic problems.

The normal grading inferred from the andalusite distribution pattern suggests that the beds at Kuala Kemasik are right side up which is consistent with the younging directions indicated by the small scale current bedding and load structures. However, in a few exceptional cases a downward increase of andalusite has been noted. This may imply either original inverse grading or overtuning of the beds. The latter seems unlikely as it contradicts the younging direction indicated by the current bedding in contiguous beds.

From the frequency of the beds (sometimes in succession, Fig. 4) that show the characteristic andalusite distribution pattern, it becomes immediately apparent that graded bedding is extremely common at Kuala Kemasik. The presence of small scale current bedding and frequent graded bedding imply a turbiditic environment of deposition of the sediments. The occurrence of thick lenticular quartzite beds with features of channel deposits may, however, suggest a shallower marine environment;

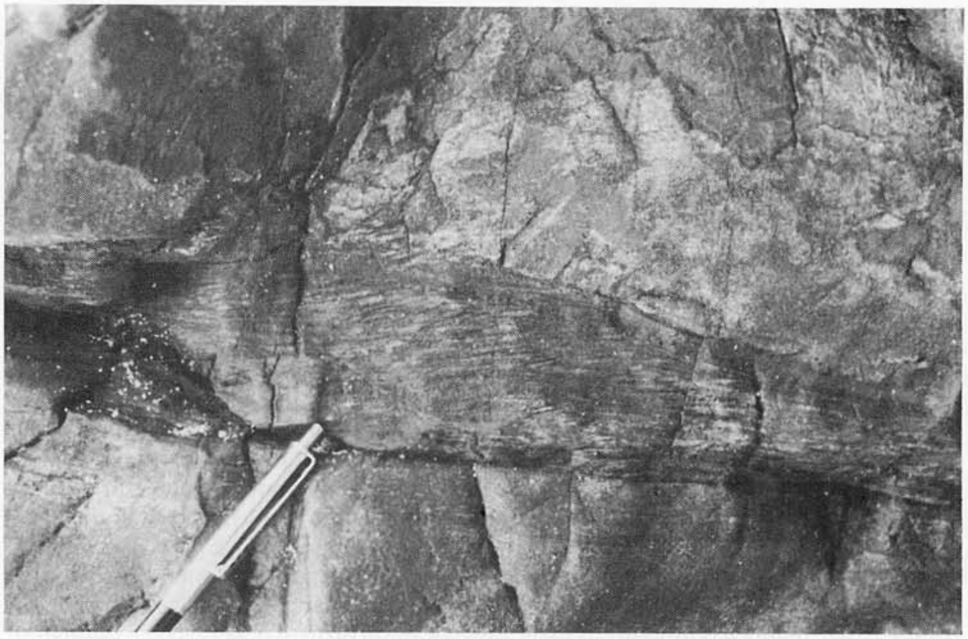

Fig. 7. Small scale current bedding in a meta-siltstone bed.

but it maybe argued that the lenticular shape of the quartzite beds is of tectonic origin inasmuch as some of them contain bedding-parallel quartz veins with pinch and swell structures. Further studies are needed to resolve the problem of depositional environment.

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