SOME CRITICAL OBSERVATIONS ON THE SAUSAR SEQUENCE

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In the last few decades divergent views have emerged on the definiteness of a sequence of the stratigraphic units of the Sausar Series that could be applicable to the whole of the manganese belt. These are examined here in the light of the author's own observations recorded during a detailed survey of the Sausar Series rocks in the northern part of the Nagpur district. The note considers at length the question of the consistency of the order of the different lithologic units of the Sausar Series given the status of the ' Stage ' and of the degree of variation in their sedimentary characters over wide regions. The possibility of the presence of many dolomitic horizons and more than one gonditic ore-bearing horizon occupying different positions in the stratigraphic sequence is discussed in the background of the concept of environmental change in space and time. The validity of the well-known criteria of rock unit correlation and top-bottom determinations in relation to the Sausar Series is also examined.

Basu (1965) in his review on the Sausar sequence has given an up-to-date account of the work done on the subject in the last few decades, beginning with the very first attempt of Sir Lewis Fermor (1921) to split the Sausar Series into stages, through works of Bhattacharji *et al.* (1922), West (1927, 1932, 1936) and Straczek and his co-workers (1956), right up to the paper of Shukla and Anandalwar (1959). Also he gave his own sequence of Sausar Series rocks (*see* Table I, column 2) as worked out from an easterly plunging syncline (Mahuli-Ramtek syncline) in an area within the Ramtek tahsil of the Nagpur district. In his criticism of the earlier work Basu (1965) states: 'It is clear that some of the fundamental stratigraphic principles have been ignored.' The Sausar succession as worked out by Fermor and West (1936) is given in Table I (column 1) which has also been accepted by the Geological Survey of India with minor modifications for the eastern part of the manganese belt. It is mainly this succession against which Basu (1965) argues. His arguments together with his own inferences may be given here in brief for a proper consideration subsequently. These are:—

' (1) In case of lithofacies change, lateral variation and intertonguing of sediments will take place, and the sequence of different lithologic units and thickness and character of the individual rock units cannot remain exactly the same in different areas over a vast region.

TABLE I

Succession worked out by Fermor and West (1936)	*Succession worked out by Basu (1965)*
	Ramtek group: Quartzite.
	Unknown rock group: Concealed under alluvial soil.
Sitapar stage: Hornblende schist	Chargaon group: Dolomite, etc., quartzites and quartz schists, dolomite, etc.
Bichua stage: Pure facies: White dolomitic marble with serpentine, tremolite and diopside. Impure facies: Diopsidites, actinolite-schist and schists with wollastonite, grossularite, tremolite and anthophyllite.	
Junawani stage: Muscovite-biotite-schist with autoclastic conglomerate.	
Chorbaoli stage (? = Ramtek stage): Quartzites and muscovite-quartz-schist.	
Mansar stage: Muscovite-biotite-sillimanite-schist with lenticular beds of manganese ore.	Mansar group: Muscovite-schist with gondite and manganese ore.
Lohangi stage: Pink calcitic marbles and calciphyres.	Ghuksi group: Dolomite. Muscovite-quartz-schist, quartzites and biotite schist.
Utekata stage: Banded calc granulites	Mahuli group: Dolomitic marble. Quartz-muscovite gneisses, diopside granulite, marble, etc., felspathic gneisses.
Kadbikhera stage: Magnetite-biotite granulites.	Kalapatha group: Calc gneisses. Pink marble occasionally with manganese ore. Calc gneisses. Pink marble occasionally with manganese ore. Calc gneisses.
	Parseoni group: Quartzites with gondites and manganese ore.

From the present state of our knowledge about stratigraphic principles it is most unlikely and perhaps impossible that in the Sausar Series rocks, originally consisting mainly of sandstones, shales, limestones, dolomites and manganiferous sediments, etc. (metamorphic equivalents being quartzite, mica-schist, calcitic and dolomitic marbles and gondite), individual lithologic units like Bichua stage, Chorbaoli stage or Mansar stage, etc., will occur as persistent lithotopes over thousands of square miles maintaining the same sequence everywhere.

' (2) Laterally marbles and calc silicate rocks grade into schists. It is, therefore, not clear why the different formations have been placed one above the other in a stratigraphic sequence.

' (3) Stratigraphic sequence is based not on lithology alone but on the stratal continuity and on the superposition of the different units or groups, lithologic characters of which may vary from place to place. Against this basic principle the previous authors tried to correlate a quartzite horizon in any part of this vast region either with the Chorbaoli stage or with the Sitasaongi stage, assuming this as a lithotope persistent over wide regions without showing valid reasons for such assumption. Thus Ramtek quartzite, which was placed as the youngest formation of the Sausar Series in the Ramtek area by Bhattacharji on structural evidence, was grouped with the Chorbaoli stage (a lower horizon in the succession) purely on lithological grounds by West with the assumption that two quartzite horizons cannot appear in the Sausar sequence. Where more than one quartzite horizon occur in a sequence they are assumed to be repeated by folding or faulting.

' Any dolomitic horizon occurring in any part of this vast region occupied by the Sausar Series has been correlated with the Bichua stage with the obvious assumption that more than one dolomitic horizon cannot be present and that one such band cannot laterally branch into several dolomitic bands. Where two or more dolomite bands appear in a sequence they have been interpreted as repetition due to folding or faulting without giving sufficient structural evidence.'

Basu is of the view that there are at least two gonditic ore-bearing horizons and more than five dolomitic rock bands occupying different positions in the stratigraphic sequence of the Mahuli-Ramtek area.

The author of the present note has studied during the last three years the metamorphic rocks of the Sausar Series in the northern part of the Nagpur district, carrying out a detailed lithologic and structural mapping on 2-inches-to-a-mile scale of the Chorbaoli-Junawani area that forms the northern portion of the one-inch sheet, 55 0/7. We shall consider in the following paragraphs the above-mentioned arguments and inferences of Basu, together with certain other problems concerning the Sausar sequence in the light of the author's own observations, with regard to the behaviour of the different stratigraphic units recorded during the detailed survey of the Chorbaoli-Junawani tract and a reconnaissance of the neighbouring areas.

Ever since Fermor completed his investigation of the Sausar belt many new concepts and methods of research have been evolved in the field of pre-Cambrian geology. While these may provide a new line of thought or a better approach to a problem, they never lessen the importance of the observations recorded by the pioneer workers, on which the present-day investigations are in many respects still founded. Basu's attempt to apply the facies concept to the Sausar sequence deserves much appreciation, but he

seems to have based his arguments more on the well-established theories of 'Sedimentary environments and facies' than on actual evidence gathered from the Sausar Series itself.

As regards the oldest or the youngest stratigraphic unit of the Sausar sequence, the earlier workers, in fact, do not seem to have provided much scope for any strong difference of opinion as, for example, West (1936) himself states: 'The order could be reversed without much difficulty as the folds are mostly isoclinal.' What requires our attention more is the question raised by Basu (1965) of the consistency of the order of the different lithologic units given the status of the stages and of the degree of variation in their sedimentary characters observed over wide regions. Let us consider the view expressed by him in (1). While intertonguing of sediments and variation in the character and thickness of the individual lithologic units over a vast region are phenomena well expected in lithofacies change, it seems too much to assert that the sequence of the different rock units cannot remain constant over their areal extent. As regards the expanse, the 'Sausar basin', visualized so vast by Basu, is just a patch when compared with the mighty 'Vindhyan basin', not much different from the former in the assemblage of the sedimentary rock types to its north. Emphasizing the striking persistence and uniformity of the Upper Vindhyans (> 12,000′ thick; dominantly sandstone, shales and limestone), Pascoe (1950) writes: 'The general composition and arrangement of the Upper Vindhyan rocks is strikingly uniform, and in spite of their obviously shallow-water nature, one of the most interesting and characteristic features of the group is the extraordinary persistence over the greater part of the great basin, not only of the chief but also of the most minor subdivisions.' Regarding the Lower Vindhyans (> 3,000′ thick; predominantly shales and limestones, also sandstone), which lack the definiteness of that of the Upper group, Pascoe (1950) writes: 'The zones of subdivisions are not well marked and all members of the series are not persistent in every section, irregularity being due partly to thinning out and partly to lateral change. The conspicuous want of constancy in the case of the first beds laid down is due to the unevenness of the floor of older rocks upon which they were deposited. Conditions of sedimentation became more uniform as the irregularities of this floor became filled up and smoothed off.' From this it is evident that the sequence of the different lithologic units is fairly constant over the greater part of the Vindhyan basin. Thus it is no surprise, and definitely not impossible, to find the sequence of superposed lithotopes fairly constant over the greater part of even a great basin, though each rock unit may show lateral variation in character and thickness.

We can now consider the important question of the degree of persistence of different rock units and examine at the same time the possibility, if any, of the variation in the sequence of the various stratigraphic units of the

Sausar Series over different parts of the belt. The author's own observations combined with those recorded by a recent team of workers headed by J. A. Straczek (1956) on the manganese ore belt suggest that most of the stages—Utekata, Lohangi, Mansar, Chorbaoli and Bichua—however thin, discontinuous and lenticular, are fairly persistent over the greater part of their areal extent. To give a concrete example, the banded calc granulites of the Utekata stage, one of the most easily recognized horizons, have been followed without a break and without undergoing any sufficient change for at least 50 miles along the strike (West*). As regards the variation in the sequence of the stages over wide regions, although a complete succession of the Sausar Series has not been encountered in any one section, inconsistency in the order of the stratigraphic units has not been reported so far. On the other hand the order of succession of the stages is maintained over a large area. This shows that Basu's statement has hardly any bearing on the actual behaviour of these stratigraphic units. Moreover, he does not provide any evidence, much less a geological map, to support his view.

Considering the point raised by Basu in (2), it may be said that lateral gradation of marbles and calc silicate rocks into schists concerns a single stratigraphic unit and is a case of facies change from calcareous to argillaceous, indicating thereby a lateral shift in the depositional environment. But that is no reason why a schist occurring in the sequence as a fairly persistent band, above or below the above-mentioned horizon, should not be given the status of a separate stratigraphic unit, especially when its lithology clearly indicates a vertical shift in the sedimentary environment.

Here it may be pointed out that in case one or more stages of the Sausar Series are characterized by facies change, and the section under investigation falls in the zone of marked intertonguing, some mistakes will creep in in the succession because such a section may include the rock formations of the two facies of the same rock unit in vertically successive alternations (Cooper and Cooper 1946). Nevertheless such mistakes automatically become obvious and are set right as the study is extended to the sections away from the zone of intertonguing where only one of the two facies of the rock unit will prevail, the other having died out.

Let us now come to the arguments of Basu contained in (3). It is true that stratigraphic sequence is based not on lithology alone but also on the stratal continuity and on the superposition of the individual stratigraphic units which may show inconsistent sedimentary properties from place to place. And ' the concept of environmental change in space and time—and of lateral and vertical shifts in lithology and fauna in response to environment—is a recognized and accepted part of stratigraphic thought (Krumbein and Sloss

* Personal communication.

1951). The Sausar Series yields clear evidence of the change of depositional environment with advancing time as expressed by the presence of a succession of superposed lithotopes—argillaceous, arenaceous, calcareous, magnesian and manganiferous—mostly with sharp contacts, except the boundary between the Utekata and Lohangi stages which is gradational, in the stratigraphic column as observed in many sections in Sausar, Deolapar, Chorbaoli-Junawani and other areas. However, it has to be seen what evidence, and to what degree, do the Sausars offer to show environmental changes in space, i.e. variation in lithologic character of the individual stratigraphic units over their areal extent. Among the different horizons, the Chorbaoli stage gives indications of such changes, its quartzites and muscovite-quartz-schists passing into one another laterally with interfingering at places. Considering the Sausar belt as a whole, eastward the calcareous and the magnesian members of the sequence die out, being replaced by the argillaceous members, i.e. phyllites, quartzites, greenstones and manganese ore, constituting the Chilpi Ghat Series. However, this change in space in the character of deposition has to be thought of with some reservations as Fermor (1936) states:

> 'We are bound, on the evidence, to accept as the probable interpretation of the facts that the Chilpi Ghat and Sausar Series are two aspects of the same period of deposition. The Chilpi Ghat Series as exposed does not necessarily include the equivalents of the lowest beds of the Sausars, and may include beds higher than the highest yet detected in the Sausars. The absence of calcareous members may be largely due to lateral change, but it may also be partly due to the shearing out of the lower members of the Chilpi Ghat Series in Balaghat. There is no evidence one way or the other on this latter point.
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> 'Perhaps the interpretation is that the Chilpi end is the portion of a basin of deposition nearest to land or to a debouching river system, and the Sausar end, the portion furthest away, the greater proportions of the chemical sediments being deposited furthest from the source of supply.'

Thus the evidence presented by Sausar Series of changes in the depositional environment in space is limited.

Now, it has to be decided which of the known criteria of rock unit correlation—(1) lateral continuity, (2) lithologic identity including thickness, cross-lamination, ripple marks and other structural features, (3) guide fossils, (4) position in the sequence—can be used best to determine the equivalency of the stratigraphic units in the present region of high degree metamorphism and structural complexity. Examining the validity of the above-mentioned criteria of rock unit correlation, it seems that leaving the criterion (3) all others can be quite effective in any pre-Cambrian terrain when used in conjunction. While correlating the rock units of the Sausar Series the previous workers obviously, and very correctly, followed these criteria as the nature of the tract left them with no choice. And the horizon comprising the quartzite and muscovite-quartz-schists—the Chorbaoli stage—has been correlated with another such horizon, not relying on the lithologic identity alone but also on

the basis of lateral continuity and position in the sequence. As regards the composition of the Chorbaoli stage, the author fully agrees with West as his own observations in the Chorbaoli-Junawani area, where the stage is very well developed, show it to be composed of quartzites and muscovite-quartz-schists with lateral gradations of one formation into another. Similarly the correlation of the dolomitic horizon—the Bichua stage—has definitely not been attempted on the sheer assumption that more than one dolomitic horizon cannot exist in the sequence and that one such band cannot laterally branch into several dolomitic bands, as misrepresented by Basu (1965). On the other hand definite criteria of rock unit correlation, referred to above, always formed the basis of such an attempt. Emphasizing the effectiveness of using the 'position in sequence' as a criterion to determine the equivalency of the stratigraphic unit, Krumbein and Sloss (1951) state:

> 'Under normal circumstances each lithologic unit possesses a unique position with reference to other units above and below.
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> 'In any area under study, there may well occur three limestone units with such similarity of lithology as to prevent their correlation in isolated exposures. The chances are remote, however, that each limestone bears the same relation to other lithologies in the sequence. Thus one limestone may rest upon a shale and be succeeded by a sandstone, a second limestone may rest upon a dolomite and be succeeded by red beds. In each case it is not the lithology of the individual limestone unit which makes correlation possible, but the position of that unit with reference to the determined sequence of units in the area.'

This was the main argument West (1931) used when introducing some of the stages of the Sausar Series which Fermor had thought to be of igneous origin. When a particular rock of well-marked characteristics is both overlain and underlain by rocks of equally well-marked characteristics, it is a strong presumption that if a similar succession is found elsewhere, it is the same.

Basu (1965) has expressed the possibility that the presence of more than one dolomitic horizon may be due to the branching laterally of one such band, but has refrained from verifying if all these bands, when traced laterally, join into one. The existence in the Sausar sequence of more than one or even five dolomitic horizons, as inferred by Basu (1965), and that of two gonditic ore-bearing horizons is quite likely and normally should not surprise anyone. But, in view of the concept of change in depositional environment through time which the Sausars have manifested so well, it is rather curious why two such horizons occurring across the strike should be so identical in lithology and so alike in their relation to underlying and overlying rock units. Chances for such a perfect and symmetric repetition of sedimentary environments through time are, according to Krumbein and Sloss (1951), remote. And it is perhaps this fact which has led many a pre-Cambrian stratigrapher to seek the explanation of such cases in 'folding' and 'faulting'. Moreover, if the depositional environment favourable for the deposition of dolomitic sediments repeated itself more than five times in the history of the Sausar basin,

it is very unlikely that it was confined to the Mahuli-Ramtek area and, therefore, all these dolomitic horizons should be traceable elsewhere also over the Sausar belt. The same applies to the gonditic ore-bearing horizons referred to as Mansar stage. On the contrary, the existing literature on the manganese belt does not show anywhere else the presence of more than one dolomitic horizon; nor is there left any indication of two gonditic horizons if we regard the Chilpi Ghat Series with its manganese ore horizon (Balaghat and Ukwa) as the less metamorphosed form of the Sausar Series. Further, commenting on the modifications proposed by Basu in the Sausar sequence, Supriya Roy (1966) writes: 'The author feels that Basu's conclusions are based on the study of a very small part of the Sausar tract and hence his suggestions for a revision of the entire Sausar sequence should wait until supporting data are obtained from other parts as well.'

Basu perhaps could not avoid such a conclusion, hasty as it appears, because of his failure to distinguish the rock units of the Bichua stage from those of the Utekata and Lohangi stages. This is evident from the following statement of Gupta and Basu (1965): 'The rocks of the impure facies of the Bichua stage are in no way dissimilar to the rocks of the Utekata stage, described by West. Moreover, the white dolomite bed, typical of the so-called Bichua stage, often passes laterally into pink marble of the Lohangi stage. Thus it can be seen that even the identity of different stages is not possible since the characters of each of the rock units vary laterally.' Nothing could be more shocking to a geologist working in the Sausar tract than such a sweeping statement, for the fact is that the rock types of the Bichua and Utekata stages are markedly different, not only in the mineral assemblages but also in their weathering characteristics. The typical ribbed surface of the calc granulites of the Utekata stage with microcline-rich bands standing out in relief is unknown to the rocks of the impure facies of the Bichua stage, and therefore the two cannot be confused. Further, at no place in the area investigated the author had any difficulty in identification of the rock units, nor did he anywhere find the white dolomitic Bichua marbles passing laterally into the pink Lohangi marbles so distinctly different in character with frequent presence of manganese ore.

The region forming the Sausar belt is so highly metamorphosed and so intensely deformed that it has rendered the application of many a criterion of rock unit correlation and top-bottom determination difficult. This difficulty, which prevents the determination with any degree of certainty of the oldest and the youngest stratigraphic unit, has been felt ever since the study began on the isoclinally folded Sausar Series. It is equally important to mention here that the plunge of the folds cannot also be used as a reliable criterion for the determination of the sequence in a region such as this, severely affected by cross-folding which has caused not only the development

of complex closures in the formation boundaries, but also the reversal of plunge direction in places. Thus still more intensive work, both stratigraphic and structural, is required to be done before the succession established so far is modified or rejected, or a new succession applicable to the whole of the belt is evolved. Unless investigations have been carried out on a regional scale and we have sufficient evidence to support a view, it would be quite unscientific to force any phenomena on the Sausars just because they have been discovered elsewhere.

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