CHAPTER IV

STRATIGRAPHY AND DEPOSITIONAL HISTORY

GENERAL

The author, while dealing with the stratigraphy of the rocks of the area has no intention of getting into controversies or arrive at definite correlation of the rocks of his area. His attempt, here is aimed to present the sequence of the rocks on the basis of his critical analysis of structures and metamorphic characters of the various formation. A precise stratigraphical account of the rocks of Kusma-Phalebas area is rather difficult to give. Though, the area looks structurally quite simple at first sight, it reveals on a detailed investigation, a complex structural pattern, which in turn has complicated the stratigraphy too. The complete absence of fossils has made the work of correlation difficult.

Detailed mapping of the area has revealed the following field succession from south to north:

Quartzose phyllites with layers of gritty quartzose phyllites	Balewa Formation
Gritty quartzose phyllites with layers of micaceous quartzites	
Quartzites with lenses of spilites	Kusma Quartzites
—— Kusma Reverse Fault ——	
Quartzose phyllites with layers of gritty quartzose phyllites Gritty Quartzose phyllites with layers of micaceous quartzites	Balewa Formation
Quartzites with lenses of spilites	Kusma Quartzites
—— Phalebas Thrust ——	
Slaty phyllites Purple, grey and green coloured slates, dolomites and impure feldspathic sandstone (graywacke)	Sumsa Formation

The study of the sedimentary features like cross beddings, ripple marks and sun-cracks in the quartzites, slates and sandstones clearly point out their normal position in the field. Allowing for the presence of small scale tight folds and their effects locally, there has been no regional inversion of the sequence.

A close study of the various rock types of the area, their petrography and metamorphic characters, points out following two conspicuous features.

1. The sequence shows a feeble metamorphic inversion, the lowermost formation being almost unmetamorphosed but grading upward into somewhat metamorphically high grade rocks.
2. A repetition of the sequence is observed in the upper half of the succession, and this repetition is due to a high angled reverse fault at Kusma.

The correct stratigraphic positions of the various rock formations in the area was worked out taking into account the exact location of the Phalebas Thrust. Field and petrographic studies enabled the author to precisely delineate this tectonic plane. The structural framework of the rocks on either side of the thrust show quite conspicuous differences, though the tectonic history was the same. The rocks on both sides of the thrust have preserved four episodes of folding, but in details, the orientation of the successive elements exhibit a marked diversity.

Once these facts were understood, the rock formations could be adequately arranged in the following stratigraphic order:

3. Slaty phyllites; purple, gray and green coloured slates, dolomites and impure feldspathic sandstones (graywacke)	Sumsa Formation
2. Quartzose phyllites with layers of gritty quartzose phyllites; gritty quartzose phyllites with layers of micaceous quartzites.	Balewa Formation
1. Quartzites with lenses of spilites	Kusma Quartzites

STRATIGRAPHY AND AGE

In the past, several attempts have been made to correlate the rocks of Kali Gandaki Valley with the known Lesser Himalayan rocks of Kumaon and Garhwal, and also with the rocks of Eastern Himalaya and Peninsular India. Ages ranging from Precambrian to Jurassic have been assigned to these rocks. But it is quite obvious that the stratigraphy and the rocks of this region have confused most of the earlier workers.

Bordet (1961) and Bordet and others (1964), initially envisaged a Jurassic age to the rocks of the Kusma-Phalebas area, belonging to their 'Series of Kuncha', but later on Bordet (1973), correlated his 'Series of Kuncha' with the Chail series of Fuchs (1967), obviously assigning a much older age (Devonian) to these rocks.

On the other hand, Nadgir & Nanda (1966), assigned the rocks of the study area to the older beds of their Suparitar series of Precambrian age. The Balewa Formation (of the present author) is similar to Nadgir & Nanda's 'Grits and phyllites (Flysch?)', the oldest beds of Suparitar series. Similarly, the Kusma Quartzites is correlatable to their 'White quartzites' and 'Basic volcanic facies', and the dominantly grey slate succession of Sumsa Formation, outcropping in the village of Sumsa, are equivalent to the middle beds of Suparitar series i.e. 'Grey shales' and 'Purple formation' of Nadgir & Nanda (1966).

Stratigraphic interpretations of Fuchs (1967) and Fuchs & Frank (1970) are somewhat confusing, Fuchs (1967) has shown the rocks of the study area as Chail series of Devonian age, and according to him a thrust (his Chail Thrust) is cutting the rocks of the same stratigraphic age. It is interesting to observe that later on Fuchs & Frank (1970) assigned a Nagthat age to the quartzites of Nuwakot (east of the study area) these quartzites are the southeastern extension of the Kusma Quartzites of the study area. In a general way, if the ideas of these workers are applied to the sequence of the study area, the following correlation works out:

Sumsa Formation	? Chandpur (Devonian)
Balewa Formation	? Chail series (Devonian)
Kusma Quartzites	? Nagthats (Devonian - Carboniferous)

This necessitates a regional inversion, the validity of which is quite doubtful. Fuchs (1967) has shown his thrust separating the two units, only on the basis of metamorphic characters. But it is observed that his purple coloured rocks (supposed to be equivalent to Chandpurs and to the south of the thrust) are in fact gradational into the overlying grey slates (of his Chail series) across the so called thrust. Therefore, the present author has included the purple as well as grey slates together in Sumsa Formation, and has put the thrust (Phalebas Thrust) above the slates.

According to Hagen (1969), the rocks of the study area forming a part of Nawakot nappes, belong to a stratigraphic age ranging from Precambrian to Mesozoic. He correlated the rocks with Krol sequence of Auden (1937). Hagen has shown the rocks of Kusma-Phalebas area to lie near the root zones of Nawakot nappes and form a Palaeozoic or Pre-Palaeozoic sequence.

Talalov (1972), who did not visualise any thrust in this area, has shown the rock formations of the north to comprise his Upper Cambrian Okharbot suite, while those of the south (Sumsa Formation of the present author) were, according to him similar to the Lower Cambrian rocks of Tara suite.

The Japanese workers Sako and others (from Ohta & Akiba, 1973), have shown the rocks of the study area to form a part of their Middle and Upper subgroups of the Midland Meta-sediment group of Eocambrian age. The more siliceous rocks (i.e. Balewa Formation and Kusma Quartzites) are lithologically similar to Middle subgroup rocks, while the argillaceous sequence (of Sumsa Formation) are correlatable with the Upper Subgroup of the Midland Meta-sediment group.

Mention about the similar lithological types as encountered in the study area have been made by several previous workers in Eastern, Central and Western Nepal. Bordet (1961) and Bordet and others (1964), have shown their 'Series of Kuncha', similar to the rock succession of the study area, to form a wide monotonous belt not only in the Central, but also in the region east of Kathmandu. Fuchs (1967), and Fuchs & Frank (1970), have also described their Chail series, similar to the rocks of the study area to form a monotonous rock formation in the Western and Central Nepal.

More recently, Stocklin & Bhattarai (1977) in the Kathmandu section have described Lower Nawakot Group of Late Precambrian to Upper Cambrian age, which shows a great similarity with the rocks of Kusma-Phalebas area. The Balewa Formation and Kusma Quartzites are lithologically very much similar with the oldest beds of Lower Nawakot Group - 'Kuncha Formation' and 'Fagfog Quartzites'. A part of 'Dandagaon Phyllites' and 'Nourpul Formation' (middle beds of Lower Nawakot Group) are identical with the Sumsa Formation.

Mention may be made here of a few scattered radiometric age determination of the comparable lithoformations from the Lesser Himalayas of Nepal. Krummenacher (in Bordet and others, 1965), made two K/Ar determination of rocks belonging to Kuncha Formation of the Kali Gandaki Valley; one made on muscovite from a 'Kuncha sandstone' gave an age of 872 m.y., the other on uralite from a basic rock 'gabbrc' associated with Kuncha Formation, gave an age of 819±80 m.y. Talalov (1972), reported an apparent age of 1150 m.y. resulting from a K/Ar whole rock analysis of a Tama series rock (Kuncha quartz-chlorite schist of Stocklin & Bhattarai, 1977) comparable to Balewa Formation, from the lower Tamba Kosi in Eastern Nepal. The radiometric age determination of Okharbot slate from Ramdi Ghat (in Kali Gandaki Valley), equivalent to Balewa Formation of the present author, made by Talalov (1972) gave an absolute age of 530, 540±17 m.y. From the available radiometric age data, and the likely equivalence of the various comparable lithounits from different parts of Nepal Lesser Himalayas, there seems to be an aggrement among most of the earlier workers in respect of the Precambrian to Early Palaeozoic age of the rocks of Kusma-Phalebas area.

The recent work of B.N. Upreti (personal communication) in the regions south of the study area has revealed more interesting results. The stromatolitic dolomites (Phoksing Dolomites) outcropping south of the author's Sumsa Formation, according to Upreti, show the stromatolitic algal structures characteristic of Upper Precambrian to Middle Precambrian age. The combined stratigraphy of the present author and those of Upreti, shows the following sequence.

5. Sumsa Formation
4. Phoksing Dolomites
3. Bihadi Slates
2. Balewa Formation
1. Kusma Quartzites

Hence, if the contention of Upreti regarding the stromatolites is correct, the rock formation of Kusma-Phalebas area represent a Pre-Palaeozoic sequence. This is also in support of the regional stratigraphic framework presented by various earlier workers (Table IV.1).

DEPOSITIONAL HISTORY

The quartz-arenites of Kusma Quartzites, the lowermost rocks of the area, unmistakably point to their deposition in a comparatively stable shallow water basin. Maturity of sediments, the relative roundness of the clastics as well as

Table IV.1 : Correlation Table

	Hagen (1969)	Bordet a others (ar Bordet(	Remy (1975)
Sumsa Formation	Permo-Carboniferous, Triassic (unmetamorphosed sequence of Nawakot nappes)	Jurassi 'Series Kuncha' revised Devonia	Palaeozoic (grey schists and limestone and dolomite series
Balewa Formation	Palaeozoic to Pre-Palaeozoic (metamorphosed northern sequence of Nawakot nappes)	Jurassi 'Series Kuncha revised Devonia	Palaeozoic (quartzo-pelitic series)
Kusma Formation	Palaeozoic to Pre-Palaeozoic (metamorphosed northern sequence of Nawakot nappes)	Jurassi 'Series Kuncha' revised Devonia	Palaeozoic (quartzite series)

the bimodal nature of the quartz grains, all are indicative of fast rapid deposition of recycled sand from a nearby source. The association of spilite with these characteristically stable shelf deposits, is rather interesting. These, occurring as concordent lenses and showing some mixing up with the quartz grains, represent penecontemporaneous volcanism. Though such spilitic volcanic rocks are typical of the earliest phase of a geosynclinal sequence, it is not very clear as to how they occur in association with a mature rock like quartz-arenite, pointing to a stable shelf environment. In any case, they do point to the tectonic instability of the basin.

A marked change in the nature of sediment influx is indicated in the overlying Balewa Formation. Showing a distinct graywacke affinity (Table IV.2), the sediments with their coarseness and immaturity and frequent association of graded bedding indicate their rapid dumping from a nearby provenance, in the deposition of which, the turbidity currents having played quite a significant role from time to time. Repetitive graded bedding and occurrence of spilite lenses point to tectonic instability. A slight deepening of the basin might not be ruled out, but the overall shallowness is indicated by the total absence of pillow structures

Table IV.2 : Chemical analysis of some of the representative samples of Balewa Formation

Sr.No.	1	2	3	4	5	6	7	8
SiO_2	75.73	76.5	74.43	79.25	80.02	72.80	67.68	82.08
Al_2O_3	11.94	13.01	11.11	9.26	9.0	9.51	10.71	7.35
FeO	0.31	1.14	0.22	1.33	0.58	0.4	1.69	0.67
Fe_2O_3	3.40	4.05	5.77	2.66	2.21	4.39	4.69	2.72
CaO	0.07	0.21	0.42	0.07	0.28	0.07	0.03	0.21
MgO	2.83	2.83	1.57	2.19	3.37	1.87	1.64	2.21
Na_2O	2.68	2.35	2.85	3.03	1.68	5.19	3.35	2.35
K_2O	1.82	1.82	1.51	1.51	2.12	2.12	2.72	2.12
Loss in ignition	1.31	0.98	1.91	1.51	0.99	2.12	1.52	1.2
Total	100.09	100.89	99.89	100.8	100.84	99.47	100.52	100.91

in spilites. Obviously, a delicate balance between the subsidence of the basin and influx of sediments was constantly maintained. Looking to the nature of sediments, they can be considered as nearer to a shallow marine turbidites. Some of the earlier workers like Fuchs & Frank (1970) and Talalov (1972) thought these rocks to be mollasse deposits. But it is not so, and the present study supports the views of Bordet et.al. (1964) and Nadgir & Nanda (1966), who considered these as flysch.

It is not clear, how much depositional sequence is unrepresented between the Balewa and the Bihadi Slates in this part of the Gandaki Valley. But looking to the stratigraphic sequences described by earlier workers, it is not unreasonable to assume that the Bihadi Slates come above the Balewa Formation without any significant gap. Based on the present author's reconnaissance traverses and the details made available by B.N. Upreti (personal communication), the sequence - carbonaceous slates (Bihadi Slates) and dolomites (Phoksing Dolomites) indicate an initial euxinic condition followed by that of a shallow water tidal-flat environment. During the deposition of carbonaceous slates, relatively quiet depositional environment with little influx of material from the landward side is indicated. The euxinic conditions could be generated on account of restraints imposed upon normal marine circulation, by encircling banks or by tectonic effects on topography, which create deoxygenated still bottom environment. When such carbonaceous shales are intergradational with argillaceous carbonates (as it happens in the present case), they typically constitute important elements in cratonic interior basins or marginal basins. On the other hand, the stromatolitic dolomite beds point to profuse algal activity in an inter-tidal zone, accompanied by almost total inhibition of detrital influx. These comprise mainly a carbonate mud in such tidal-flat environment which were subjected to intermittent flooding and exposure. Frequent layers of intraclastic dolomites point to the penecontemporaneous breaking up and redeposition of weakly cemented carbonate sediments. This could be brought about by the erosive activity of the tidal waves. But on the whole, tectonic quiescence is envisaged.

The Sumsa Formation, into which the dolomites grade upwards through a conspicuous zone which is made up of intercalations of purple slates and nonstromatolitic dolomites, again signifies a marked environmental change. The transitional zone, forming the lower part of Sumsa Formation, also points to inter-tidal depositional environment, which was characterised by periodic influx of argillaceous material. So much so that the sediments were subaerially exposed (purple colour and sun-cracks) from time to time. In between, carbonate layers were deposited. The upper part of the formation, i.e. beds of grey slates and graywackes, is indicative of basin subsidence and again a period of tectonic instability. The resulting rocks in their lithology and sedimentary structures, ideally reflect a shallow marine deposition.

The varied lithology, structure and texture of the sedimentary sequence reveal an interesting depositional history - characterised by a delicate combination of sediment influx and the tectonism of the basin as well as the provenance. Though the entire succession points to deposition of sediments in an unmistakable marine environment, it is clearly borne out that all the time shallow water conditions prevailed. However, the conditions fluctuated from relatively deep shallow to almost subaerial, and at the same time the rate and nature of sediment influx also fluctuated. The entire sequence typically points to a succession of deposits that characterise partly cratonic and partly geosynclinal.

But the author must confess that at this stage of his investigation,and that too in a small area, he is not in a position to fully understand the exact depositional nature.