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Sedimentary Environments of the Main Part of the Kumano Group

(A Study of the Tertiary Formations of the Kumano Coal-field
in the Kii Peninsula, Southwest Japan, Part 2)

Kazutoyo CHIJIWA and Suzuomi TOMITA

Abstract

The main part of the Kumano Group is characterized by a rhythmic succession of the sediments which accumulated in offshore marine, marginal marine and barrier island environments. The offshore facies consists of generally massive and poorly sorted sandy siltstone and mudstone, and yields marine benthic fossils. The transition from the offshore facies to the marginal marine facies is represented by gradual increase of well-bedded sandstones which become thicker and coarser-grained upwards, and exhibit small-scale cross-bedding. Farther up in the section, corresponding to the barrier island facies, sediments are composed mainly of very thick-bedded, medium- to coarse-grained sandstones which commonly show cross- and plane-lamination. In the section from the alternating beds to the lower part of this unit many burrows including *Ophiomorpha* are commonly found, and in the upper part of thick sandstone unit, thin coal seams that were produced in coastal swamps are intercalated. The change from the barrier island facies to the succeeding marine mudstone facies is generally rather abrupt. The cyclic succession of lithofacies recognized in the Kumano Group is considered to have been produced by periodic progradation and retrogradation of the strands.

I. Introduction

The Kumano Group in the southeastern part of the Kii Peninsula is one of the Miocene strata that are isolatedly distributed in the outermost side of the Outer Zone of Southwest Japan. Unlike the mostly marine Miocene strata of other regions of the Outer Zone, this group is unique in exhibiting a rhythmic succession of offshore marine and shoreline sediments and in having some coal seams in its main part. This implies that the Kumano Group involves sediments in the marginal part (basin-rim sediments) of Miocene sedimentary basins that faced to the Pacific. Above all the main part of the group really provides various features that are useful not only for interpretation of sedimentary environment and framework but also for inferences about tectonic movements in the Outer Zone of Southwest Japan or changes of sea level during Miocene times.

In the first report of this series of papers, we have described the stratigraphy and lithology of the Kumano Group with remarks on sedimentary structures (CHIJIWA and TOMITA, 1981). The present paper deals with the sedimentary environments of the Kumano Group mainly in the southern district based on the data obtained through the field observations on vertical changes of lithofacies and sequences of physical and biogenic sedimentary structures, and on paleocurrent orientation, combined with the lithostratigraphic sequences mentioned in the first paper.

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II. Summary of stratigraphy

The Kumano Group of Middle Miocene age is widely distributed in the boundary area of three prefectures, Nara, Mie and Wakayama. It overlies the Shimantogawa Supergroup with a distinct unconformity and is overlain by the Kumano acidic rocks. It is about 1800 m thick, and three divisions, namely, the Onuma, the Koguchi and the Mitsuno Formations in ascending order, have been set up on a lithological basis in the group of the study area (Fig. 1; CHIJIWA and TOMITA, 1981).

The Onuma Formation is composed of sandstone or locally conglomerate in the basal part, hard black siltstone in the lower part, conglomerate in the middle part, and alternating beds of sandstone and shale in the upper part. Some gastropods including *Turritella* sp. were obtained from the basal massive sandstone bed. This formation thins out towards the south, being restricted in distribution to the northern district*.

The Koguchi Formation conformably covers the Onuma Formation in the northern district, but lies directly on the basement rocks with an unconformity in the southern district. It is divided into three members, the Ohara, Shikiya and Koguchi members in ascending order. The Ohara Member is a conglomerate bed and is overlain by a thick siltstone of the Shikiya Member which is, in turn, succeeded by alternating beds of sandstone and siltstone of the Koguchi Member. The upper part of the last member becomes rich in sandstone and

* The geographical division of the study area is explained in the footnote of the first report.

gradually passes into the sandstone member of the overlying Mitsuno Formation. The occurrence of various species of bivalves and planktonic and benthic foraminifers from the Koguchi Formation suggests that this formation was formed in a marine environment (MITI, 1979). It increases in thickness towards the south.

The Mitsuno Formation consists of sandstone, siltstone and alternating sandstone and mudstone with some intercalations of conglomerate and coal, and shows complex facies changes. It is distinguished from the underlying two formations by such features as the predominance of coarse-grained clastics, abundant trace fossils of various kinds, and a good deal of coaly matter. Moreover, it shows a different lithofacies between the northern and southern districts. The four members are defined by lithofacies in this formation of the northern district, while in the southern district, the same formation is divided into seven members. These members of the two districts are in an interfingering relationship except the lowermost Miyai coal-bearing Member, which is common to both districts. Bivalve and foraminiferal fossils occur from each member of the Miyai, Akagi and Oyama of this formation (TANAI and MIZUNO, 1954; MURAYAMA, 1954; and MITI, 1979).

The Kumano Group is gently inclined, and shows a marked contrast in geologic structure with the basement Shimantogawa Supergroup which is intensely folded and faulted. It runs in the NNE-SSW direction bordering along the western end of the Kumano acidic rocks, and forms an opened semi-basin structure (MATSUSHITA, 1971).

Recently, HISATOMI (1981) studied the Kumano Group in the southernmost district including the coastal parts of the Kii Peninsula near the cape of Shiono-Misaki. According to him this group is lithologically divided into three formations, the Shimosato, Shikiya and Mitsuno formations in ascending order, and has a total thickness of about 4000 m or more. He has mentioned that the Shimosato Formation is correlated with the Onuma Formation in the northern district.

III. Vertical change of lithofacies

The general lithofacies of each member of the Kumano Group has been described in the first paper (CHIJIWA and TOMITA, 1981). The present paper deals with the regional variations of stratigraphic sequences and sedimentary features including lithofacies, and especially with the cycle of sedimentation recognized in the southern district.

As described previously, the Koguchi Formation is composed of the basal member of conglomerate, the siltstone member and the alternating sandstone and siltstone member in ascending order, the last of which is accompanied at intervals by massive siltstone layers. It shows a tendency of upward-coarsening and upward-thickening of sandy layers, that is, intercalated sandstone layers increase in thickness and frequency upwards. The uppermost part of this formation contains massive sandstone at irregular intervals, and finally changes

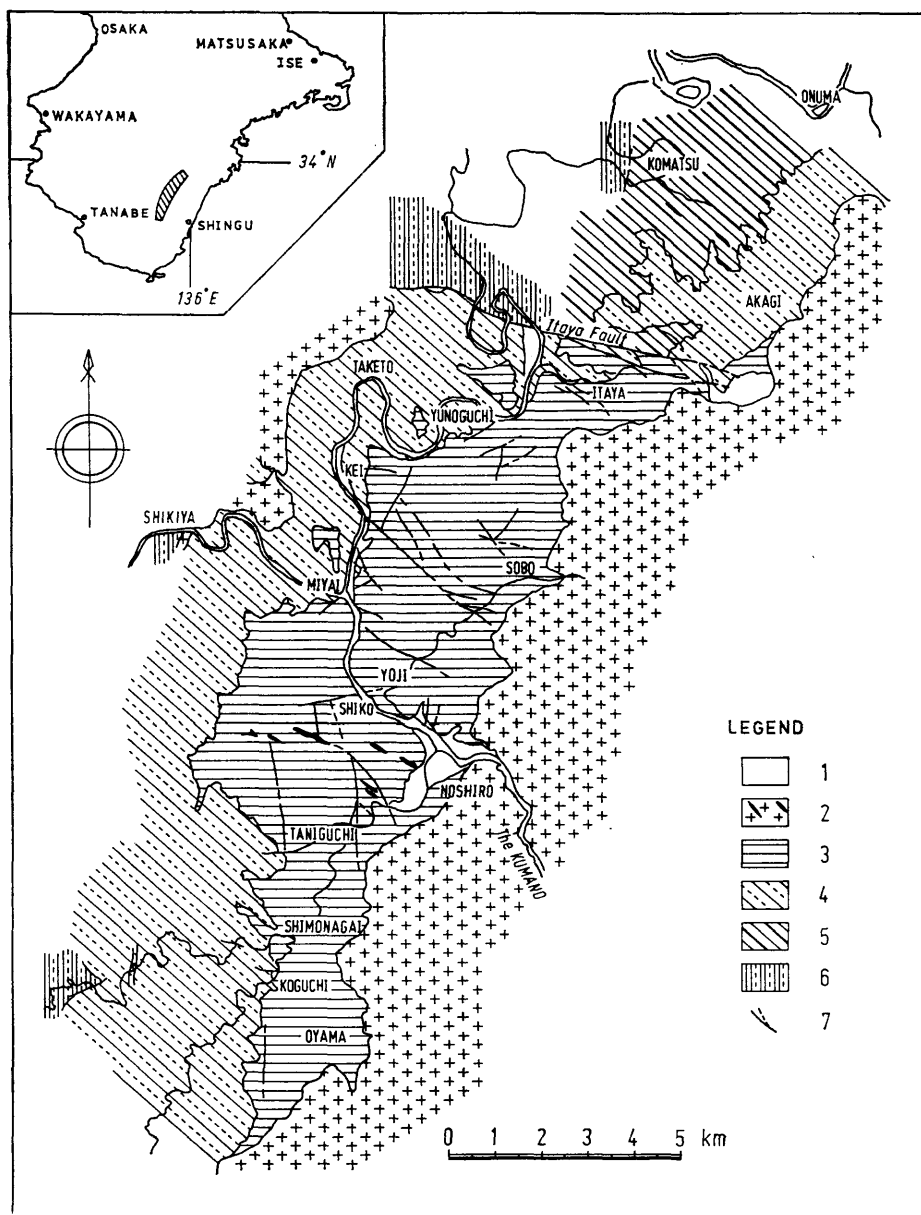


Fig. 1. Simplified geological map of the study area.

1. Alluvium; 2. Igneous rocks; 3-5. Kumano Group (3. Mitsuno Formation, 4. Koguchi Formation, 5. Onuma Formation); 6. Basement rocks (Shimanto-gawa Supergroup); 7. Fault.

gradually to thick massive sandstones of the basal part of the Mitsuno Formation (Fig. 2).

The Miyai coal-bearing Member, the lowermost unit of the Mitsuno Formation, consists mainly of medium- to coarse-grained sandstone and con-

glomeratic sandstone with one or two, about 30 cm thick, coal seams in the middle part. Conglomeratic beds contain well rounded gravels. Sandstones are generally massive but sometimes show parallel lamination, cross-bedding, and horizontal bedding which is much more clearly demarcated than laminae. Biological hieroglyphs, especially burrows including *Ophiomorpha* sp. and *Thalassinoides* sp., are commonly found. Rill marks crossing the crest of asymmetrical ripple marks were found on a sandstone layer at Taniguchi.

Noteworthy is that the Miyai coal-bearing Member shows a symmetrical vertical change in lithofacies with the coal-bearing shale as a central marker bed. That is to say, a tendency of upward-fining and upward-thinning of sandstone layers is shown in the upper half of the Miyai Member, in contrast with the reverse trend of lithofacies, that is the upward-coarsening and upward-thickening sequence, in the lower part of the same member as shown in Fig. 2(C). The uppermost part of the Miyai Member somewhat increases the thickness and frequency of silty or muddy intercalations upwards, and gradually changes into the alternating beds of sandstone and mudstone of the basal part of the Taniguchi Member.

The vertical change of lithofacies from the Taniguchi to the overlying Shiko Member of the Mitsuno Formation is well observed at Shimonagai, Koguchi and Shiko of the Kumanogawa Town, Wakayama Prefecture. In the upper part of the Taniguchi Member, sandstones alternating with mudstones increase their thickness upwards. Sandstones of the Shiko Member are generally thick- to very thick-bedded, and medium- to coarse-grained. They are generally massive, but some layers show parallel- and cross-lamination and horizontal bedding. Some biogenic structures such as burrows including *Thalassinoides*, tracks and trails were found in and on the bottom of sandstone beds in the lower part. Several millimetres thick coaly laminae have been detected at two horizons in the upper part of the same member at Shimonagai (Fig. 2 -F). Calcareous nodules are also found at Yoji and Shiko. At Shiko, a thick conglomeratic sandstone of the Shiko Member rests on the mudstone of the Taniguchi Member with a sharp boundary (Fig. 2 -E), so their relation may be disconformable.

The Akagi Member is composed mainly of sandy siltstone, and shows a rather abrupt lithologic change from the underlying Shiko Member. At the boundary between the two members no such an upward-thinning and upward-fining sequence of sandy layers as observed in the uppermost part of the Miyai coal-bearing Member is recognized, but only thin alternating beds of sandstone and mudstone are observed. Some species of benthic foraminifers are reported from the Akagi Member (MITI, 1979).

The Akagi Member grades upwards into the Kowase Member with an upward-coarsening and upward-thickening sequence as illustrated in Fig. 2 (F and H). In the Kowase Member, very thick bedded, medium- to coarse-grained sandstones are dominant, but several beds of conglomerate are also intercalated. Sandstones remarkably vary in thickness and grain size, and exhibit parallel-lamination, planar- and trough-shaped cross-bedding with gently inclined foreset laminae. Burrows, tracks and trails of various forms were commonly found,

and siltstone layers are intensively bioturbated.

The overlying Oyama Member is composed of siltstone with some interbeds of sandstone, and shows an abrupt change of lithofacies from the uppermost part of the Kowase Member. It contains some fossils of planktonic and benthic foraminifers (MITI, 1979).

The Hyoren Member, the uppermost unit of the Mitsuno Formation in the southern district, consists mainly of very thick-bedded, massive, coarse-grained sandstone which occasionally shows parallel-lamination and cross-bedding. Burrows were rarely found. The boundary between this member and the underlying Oyama Member is clearly defined by an abrupt change from mudstone to thick-bedded coarse-grained sandstone as shown in Fig. 2 (G).

IV. General scheme of the sedimentary facies

The Kumano Group in the southern district consists of an alternating or cyclic sequence of coarse- and fine-grained facies. The Miyai, Shiko, Kowase, and Hyoren members are referred to the former, and the Koguchi, Taniguchi, Akagi, and Oyama members to the latter.

The members of coarse-grained lithofacies, mainly comprising medium- to coarse-grained sandstones, have many burrows and such common sedimentary structures as parallel-lamination, planar- and trough-type cross-bedding, and horizontal bedding which is much more clearly defined than laminae.

The members of fine-grained sediments are composed of massive sandy siltstone, mudstone, thin-bedded alternation of sandstone and mudstone, and some sporadical interbeds of thin-bedded sandstone. In these members tracks and trails are frequently recognized on the bottom of sandy layers, but burrows in sandstone layers are scarcely found. The Koguchi, Akagi and Oyama members yield bivalves and foraminifers, and their main part is undoubtedly marine sediments. While no marine fossils have been found from the Taniguchi Member, but it is so similar in lithology and the assemblage of sedimentary structures to the three members mentioned above that it may probably be marine sediments. The alternating beds of sandstone and siltstone commonly have parallel lamination, wavy lamination and small scale cross-bedding. Sandstone layers in the alternation usually have sharp boundaries at their top and bottom, but occasionally show graded bedding with sole marks and rarely reverse-grading.

Fig. 2. Columnar sections of the upper part of Kumano Group in the southern district.

(A) Ke-i, (B) Miyai, (C) Taniguchi, (D) Koguchi, (E) Shiko, (F) Shimonagai, (G) Noshiro, (H) Oyama.

1. sandstone and/or conglomerate; 2. alternation of sandstone and mudstone; 3. siltstone or mudstone; 4. parallel lamination; 5. cross-bedding; 6. horizontal bedding; 7. sole marking; 8. ripple mark; 9. rill mark; 10. concretion; 11. flaser bedding; 12. burrows; 13. tracks and trails; 14. plant fossil; 15. upward-coarsening; 16. upward-fining.

Thus the main part of the Kumano Group in the southern district is characterized by an alternating or cyclic sequence of a coarse sediment member and a fine sediment one which are very different not only in grain size and bedding thickness but also in the assemblage of sedimentary structures, biogenic structures and fossil contents.

The vertical sequence from the fine sediment members to the coarse sediment members is represented by a gradual change of lithofacies, an upward-coarsening and upward-thickening of sandstone beds, and a gradual increase of sandstones having thicker trough-shaped cross-bedding and clearer horizontal bedding.

On the other hand, the change of lithofacies from the coarse sediment members to the overlying fine sediment members is rather abrupt or is taken place within a thin interval, and the upward-thinning and upward-fining of sandstone beds are not so distinct. These facts indicate asymmetric cycles of sedimentation rather than symmetric ones.

The most representative sequence of cyclic sedimentation is seen in the Miyai coal-bearing Member. The general scheme of the lithofacies change in the alternating sequence of the main part of the Kumano Group can be summarized in ascending order as follows (Fig. 3):

Unit 1: Massive and/or bedded sandy siltstone or siltstone.

Unit 2: Thin- to medium-bedded alternation of sandstone and mudstone with sporadic interbeds of sandstone which have many burrows. Many tracks and trails are present. Sometimes flaser bedding is found.

Unit 3: Thick- to very thick-bedded medium- to coarse-grained sandstone rarely with conglomerate. They are generally massive but show planar and trough cross-bedding and horizontal bedding at not a few beds. Many burrows are present. The lower part of this unit yields *Ophiomorpha* which is an indicator of intertidal to shallow marine environments at the depth of about 30 m or less (WEIMER and HOYT, 1964; SELLEY, 1970; DIKE, 1972; and HOWARD, 1972).

Unit 4: Grey shale with thin beds of coal.

Unit 5: Almost the same as Unit 3 in lithofacies and sedimentary structures including biogenic ones. The upper part of this unit rarely contains thin streaks or patches of coal.

Unit 6: Thin- to medium-bedded alternation of sandstone and mudstone with sporadic interbeds of sandstone. The thickness of this unit is thinner than that of Unit 2.

Unit 7: Massive and/or bedded sandy siltstone or siltstone.

Regarding each lithologic unit tabulated above, the following sedimentary environments are deduced:

Unit 1: Grey to dark grey siltstone yields marine fossils, except for the Taniguchi Member as already mentioned. Scantiness of bedding and lamination suggests that this unit was deposited on the calm offshore seabottom below the wave-base level which is usually at the depth of 50–60 m.

Unit 2: This unit is considered to have been made in the environments shallower than Unit 1, that is, from the transitional zone between offshore and shoreface (ALLAN, 1967) to lower shoreface (REINECK and SINGH, 1973). The

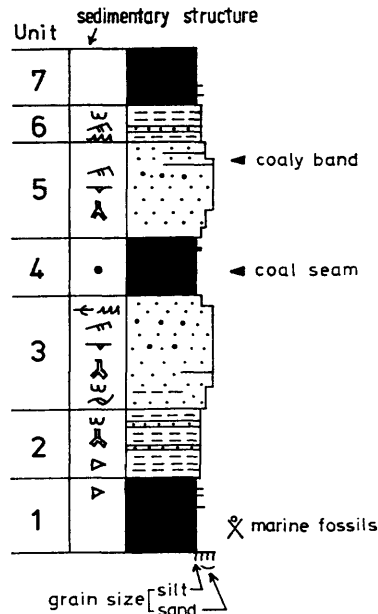


Fig. 3. Representative section of a cyclic sequence showing an upward-coarsening and upward-fining.

sharp bedding at the top and bottom of sandstones in alternating sequences and the presence of small scale cross-bedding suggest the deposition within the depth of wave-base. Graded bedding recognized in some beds and small scale cross-bedding are thought to have caused by a storm surge. Tracks and trails are commonly found on the bottom of sandstone layers. Intensively bioturbated beds are rather few, although remarkable bioturbation has been recorded from the transitional zone to the lower shoreface zone (REINECK and SINGH, 1973). *Unit 3*: Massive sandstone is probably referable to coastal and deposited in the environments ranging from upper shoreface to foreshore, sometimes to backshore defined by REINECK and SINGH (1973). No distinct dune deposits have been recognized. They seem to have removed away by erosion. No swash cross-lamination formed by swash in the foreshore zone (HARMS *et al.*, 1975) were found in this unit. Some trough-shaped cross-bedding may indicate multi-directional current flows in the surfzone, as pointed out by REINSON (1979). An asymmetrical ripple marks traversed by rill marks found in the Miyai coal-bearing Member (Plate 2, Fig. 2) is supposed to have formed in an intertidal zone.

Unit 4: Both of greyish shale sometimes containing concretions and coaly layer may be referable to the deposits in a series of environments including swamp, lagoonal pond and marsh behind a barrier.

Unit 5: Massive sandstone was produced by coastal sand as similar to Unit 3. This unit is presumed to have partly been made under the subaerial environment from the fact that very thin coal streaks are intercalated in thick-bedded sandstone of the Shiko Member at Shimonagai.

Unit 6: This unit is considered to have been made under the environments ranging from the transitional zone between offshore and shoreface to lower shoreface, similar to Unit 2.

Unit 7: This unit is considered to have deposited on the calm offshore sea-bottom below the wave-base level, similar to Unit 1.

To sum up the above description, the vertical section from Unit 1 to 7 can be regarded as the sequence of deposition in a series of environmental change from a shallow offshore marine facies through a shoreline facies including a barrier island with a temporal coastal swamp again to a shallow offshore marine facies. The lithofacies change represented by Unit 1 to 4 is referable to the product in the periods of shoreline progradation or a regressive phase. While, that of Unit 4 to 7 is considered to have resulted from a rather rapid retrogradation of shoreline or a transgressive deposition, because the overlying fine sediments yield marine fossils in most cases. The repeated occurrence of this sort of lithologic change, at least four times so far as exposed, in the main part of the Kumano Group records the periodic back and forth movements of the strands that were caused by either eustatic change of the sea level or tectonic uplift and subsidence of the basement.

The lithologic change from Unit 1 to 4 is very similar to the ideal progradational sequence depicted by RYER (1977) on the basis of the Cretaceous strata of north-central Utah, United States. In this sequence the marginal marine sediments are succeeded by coastal plain fluvial sediments. MASTERS (1967) has also mentioned that the sediments accumulated in a barrier island are overlain by the lagoonal deposits in a progradational sequence, while the beds of flood plain origin covers the mainland beach rocks. Thus, fluvial deposits commonly appear above the marginal-marine deposits in the progradational sequences. However, so far as the Kumano Group in the southern district is concerned, no such fluvial deposits have been recognized.

The coal-bearing mudstone of Unit 4 is referable to the deposits in swamp or lagoonal pond associated with marsh behind a sand barrier. ONO (1966) has reported that the coal seam has a thickness of about 90 cm at No. 9 Level and 24 cm at No. 8 Level of the Jyosen-Hon-pi Drift in the Kishu Copper Mine located at the northern extremity of the Kumano Coalfield. However, it thins only few millimetres in the borehole drilled at Miura near Sobo about 2 km east of Jyosen (MITI, 1979). This fact shows that the thickness of coal decreases remarkably eastwards. Taking up the occurrence of coaly beds in the surveyed area including the northern district, the distribution of the coal-bearing swamp deposits trends to the northeast-southwest direction.

V. Paleocurrent system

A. General remarks

Data of current directions were obtained from the field observations of directional sedimentary structures such as sole marks including flute cast, groove

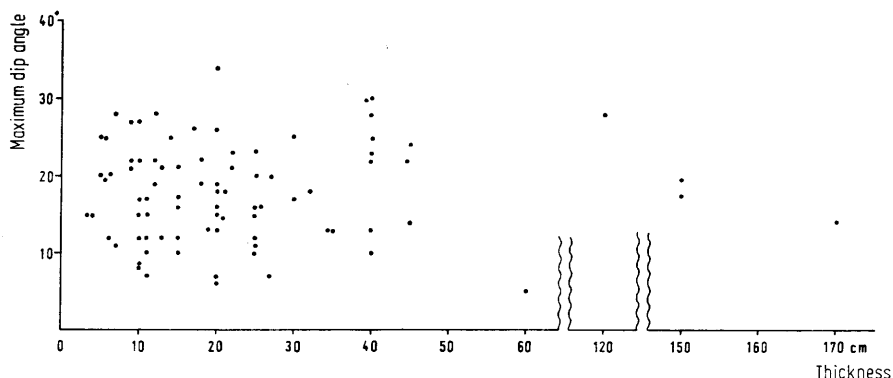


Fig. 4. Relationship between the thickness of bedding units and the maximum dip angles of cross-bedding in the Mitsuno Formation.

cast and current striation, cross-bedding and current ripple mark in the Koguchi and Mitsuno formations. 69 sole marks, 96 cross-beddings and 4 asymmetrical ripple marks were measured at 30 points. Cross-beddings were observed mostly in medium-grained sandstone. Dips of their foreset laminae were generally 28° and less. They are classified into planar- and trough-type, of which the former is dominant. Fig. 4 shows a relationship between the thickness of bedding units and the maximum foreset dip angles of cross-bedding. Most of the bedding units have a thickness of 45 cm and less with some exceptions of more than 50 cm found in the Ohkochi and the Upper Taniguchi Member in the northern district. No significant relationship was recognized between the thickness of the bedding units and the maximum foreset angles.

B. Analytical notes on the current direction

Based on the data obtained from the measuring points throughout the study area, the paleocurrent orientation is summarized in Fig. 5 as rose diagrams grouped into 20° intervals. Flute casts of the Koguchi Formation shows a tendency of the southeast and east-southeast directions. Cross-bedding azimuths measured in the Mitsuno Formation vary at every locality, but in general, they point towards the south and southeast. They show a unimodal and bimodal distribution, sometimes with bipolar patterns. Occasionally a polymodal azimuth pattern has been recognized in some areas. The mean vector of paleocurrent directions of the asymmetrical ripple marks varies from 160° to 170° in azimuth, and is in accord with the trend determined by cross-beddings at the same localities. At Oyama, however, the southwestward direction of flute casts that was found in the sandstone layer of the Kowase Member crosses almost at right angles the current direction obtained from cross-beddings in the neighbouring localities.

Fig. 6 exhibits the cumulative distributions of cross-bedding foreset azimuths in each member of the Mitsuno Formation. The prevailing direction in the Miyai coal-bearing Member trends east and southwest. The dominant directions

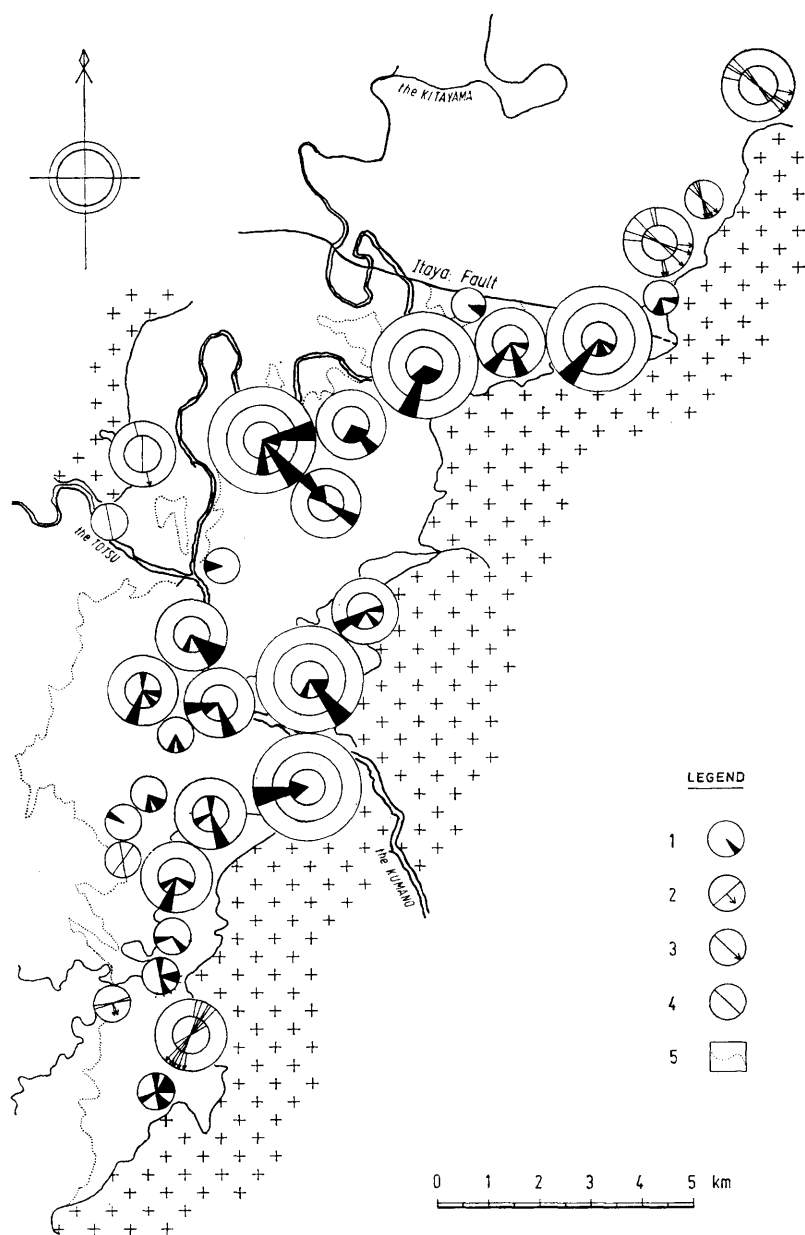


Fig. 5. Cross-bedding azimuths and directional features obtained from the Kumano Group.

1. cross-bedding; 2. ripple mark; 3. flute cast (sense known); 4. groove cast and current striation (sense unknown); 5. boundary between the Mitsuno Formation and the Koguchi Formation.

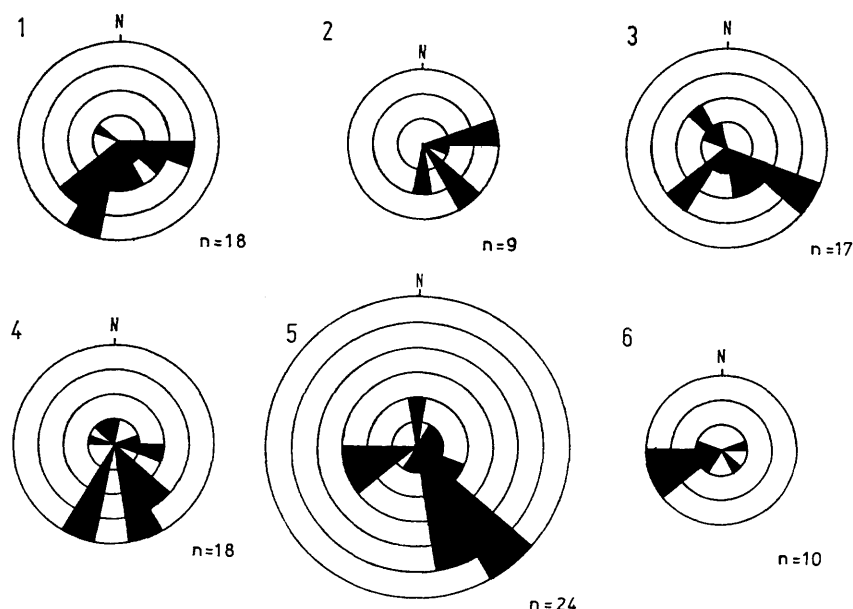


Fig. 6. Frequency distribution of cross-bedding dip azimuths in each member of the Mitsuno Formation.

1. Miyai coal-bearing member; 2. Lower Taniguchi Member; 3. Upper Taniguchi Member; 4. Shiko Member; 5. Kowase Member; 6. Hyoren Member.

are towards east to south in the Lower Taniguchi Member of the northern district. That of the Upper Taniguchi Member is remarkably diverged south-eastward and north-westward. The current directions ranging from the south-east to the southwest are dominant in the Shiko Member. In the Kowase Member the dominant orientation trends to southeast and to the west. In the Hyoren Member the westward trend is noticeable.

As mentioned above, the direction of the sediment transporting system observed in the Mitsuno Formation is fairly dispersed with a bimodal or poly-modal distribution pattern in each member, but the grand mean direction trends to the east, south or southwest throughout. The paleocurrent direction trending from the north to the south has been shown by HISATOMI (1981) in the southernmost district from the data on current marks, ripple marks and fabrics of the Kumano Group, and it is in accord with the general trend observed in the present area.

The analytical data of the directional structures suggest that there is no overall difference in the paleocurrent system between the Koguchi and the Mitsuno Formation, although there are distinct differences in lithofacies between the two formations as mentioned in the preceding chapter.

C. Discussion

For the paleogeographic reconstruction of a sedimentary basin, the paleo-current analysis is effective, and it has been indicated that the dispersal pattern of current azimuths is intimately related to the sedimentary environment (e.g. KLEIN, 1967; SELLEY, 1968 and 1970; and POTTER and PETTIJOHN, 1977). KLEIN (1967), in studying the sedimentary structures of Recent coastal sediments, recognized that bimodal dispersal patterns characterize beach sediments, and that reversal directional properties are also common because of the existence of tidal currents and wave swash. SELLEY (1968) has likewise pointed out that shoreline deposits are characterized by bimodal patterns that are attributable to the deflection of tidal currents, although unimodal and polymodal ones are also known.

In the sandstone prevailing members of the Mitsuno Formation, the current directions deduced from cross-bedding indicate an unimodal or bimodal dispersal pattern, or sometimes bipolar ones with mutually opposed modes. This high dispersion suggests that the Mitsuno Formation was developed on shoreline sand bars influenced dominantly by tidal currents.

The Mitsuno Formation shows a general orientation of paleocurrent trending the northwest to the southeast in common with that of the Koguchi Formation, and its sandstone bodies have an elongate trend directed from the northeast to the southwest in parallel with a general geometry of the sedimentary basin of the Kumano Group. PICARD (1967) who studied the directional structures in the shoreline sediments has mentioned that the dominant paleocurrent directions are at a right angle to the paleo-shoreline estimated by the known sandstone-body trends. From this it may be inferred that the paleo-shoreline had been running from the northeast or east to the southwest or west during the deposition of the Koguchi and the Mitsuno Formation. This interpretation may be supported by the facts that the Koguchi Formation increases in thickness towards the south as described in our previous paper (CHIJIWA and TOMITA, 1981), and that the imbricated slump structure shown in Fig. 8c of the same paper has a southeast vergence and is thought to be the product on a slope which inclined to the southeast.

The southwestward direction of the paleocurrent measured from flute casts in the Kowase Member may be an unusual feature caused by a temporal strong longshore current along the beach. It may be regarded that the cross-beddings of the Mitsuno Formation was formed under the influence of rip current pointed out by MASTERS (1967) and EMBRY and REINSON (1974). On the other hand, sole markings such as a flute cast, groove cast and current striation in the Koguchi Formation seem to be a product of the turbulent flow originated by storm surge.

VI. Conclusion

The second paper on the Kumano Coal-field dealt with the sedimentary facies of the main part of the Kumano Group, especially in the southern district

in order to deduce the depositional environments. The results are as follows:

1. The Kumano Group in the southern district is characterized by a cyclic sedimentation of nearshore marine environment originated from the progradation and retrogradation of sea coast.
2. The progradations of sea coast formed the upward-coarsening, or regressive, sequences closely similar with the ideal progradational sequence indicated by RYER (1977) from various evidences including lithofacies, sedimentary structures and trace fossils. Since the massive coarse-grained sandstone probably originated from beach sandstone is not overlain by any flood plain deposits but by the coal seam or shale estimated as the deposits of swamp, lagoonal pond or marsh, it is suggestive that the upper part of Kumano Group was formed in the setting of barrier island rather than in the condition of mainland beach.
3. The clastic material of this group is assumed to have been derived from a hinterland existed to the north or northwest because the southeast- or southwestward paleocurrent directions are dominant.
4. It may probably be regarded that the paleo-shoreline ran from the northeast or east to the southwest or west and was roughly in parallel with the general elongation trend of the rock-bodies.

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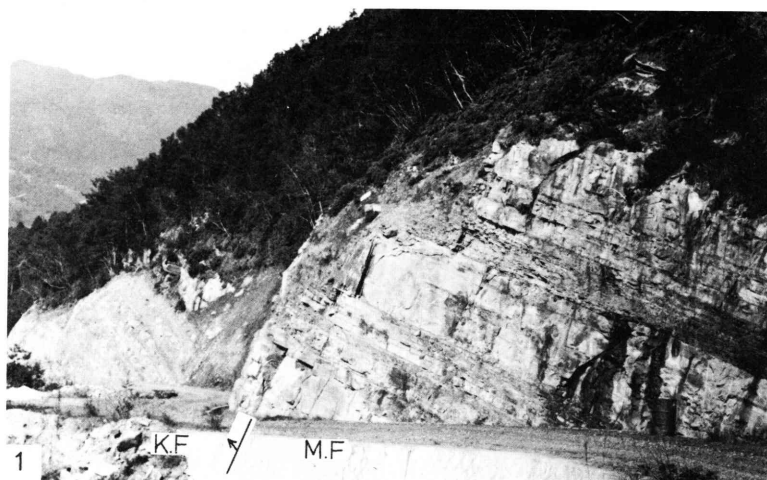
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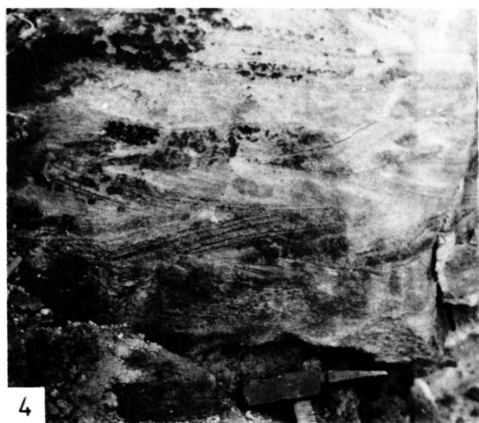
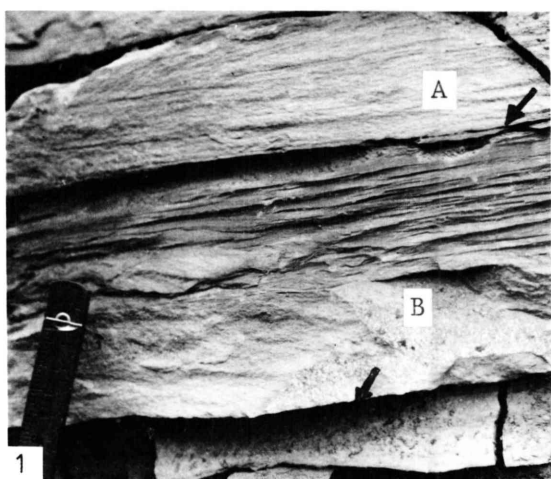
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Appendix

Alphabetical index of place names with Japanese writing

Akagi	赤	木	Oyama	大	山
Hyoren	兵	連	Shiko	志	古
Itaya	板	屋	Shikiya	敷	屋
Jyosen	上	川	Shimonagai	下	長井
Ke-i	花	井	Shimosato	下	里
Koguchi	小	口	Shio-no-misaki	潮	岬
Komatsu	小	松	Sobo	惣	房
Kowase	小	和瀬	Taketo	竹	筒
Kumanogawa	熊	野川	Taniguchi	谷	口
Mitsuno	三	津野	Yoji	楊	枝
Miura	三	浦	Yunoguchi	湯	ノ口
Noshiro	能	城	Wakayama	和	歌山
Onuma	大	沼			





Explanation of Plate 19

- Fig. 1. Outcrop showing the upward-thickening sequence near the boundary between the Mitsuno Formation (M.F) and the Koguchi Formation (K.F).
- Fig. 2. Asymmetrical ripple marks traversed by rill marks on the upper surface of a thick bed of medium-grained sandstone in the Miyai coal-bearing Member at Taniguchi.
- Fig. 3. Lenticular beds of cross-bedded, fine-grained sandstone interbedded with shale in the Miyai Member at Ke-i.

Explanation of Plate 20

- Fig. 1. Graded bedding in the Shikiya Member.
Note a sharp basal contact (arrow mark) of fine-grained sandstone grading upwards to argillite. The sandstone marked with 'A' shows only parallel lamination, but 'B' shows cross-bedding in its lower part.
- Fig. 2. Flute casts on the bottom of a fine-grained sandstone in the Koguchi Member at Akagi, partly deformed by loading.
- Fig. 3. Reverse grading in the Koguchi Member.
Note the sharp basal boundaries of siltstone which grade upward into fine-grained sandstone.
- Fig. 4. Trough-shaped cross-bedding in a coarse-grained sandstone of the Lower Taniguchi Member.
- Fig. 5. Unidirectional planar-type cross-bedding in tabular sets of a coarse-grained sandstone of the Kowase Member.