5

LITHOSTRATIGRAPHY AND FIELD DESCRIPTION

CHAPTER 5

LITHOSTRATIGRAPHY AND FIELD DESCRIPTION

GENERAL

The exposed Quaternary continental succession of the Mainland Gujarat, comprises sediments of marine, fluvial, fluvio-marine and aeolian origins (Pant and Chamyal, 1990). The various sedimentological parameters like sedimentary structures, textural characteristics and mineralogy, typically reflect the influence of the related depositional environments and mode of deposition controlling them. A total thickness of over 800 m of Quaternary sediments has been computed on the basis of exposed succession and sub-surface bore hole data (Roy, 1990). As such the nature of the base of Quaternary deposits is not fully understood and little information is available to delineate the boundary between the Quaternary and the Tertiary.

The Quaternary deposition both on Mainland and on the east coast of Saurashtra (overlooking the Gulf of Cambay) comprises part and parcel of the Cambay Basin sedimentation. A synoptic view of the Cambay Basin sequences consisting of Tertiary and Quaternary as given by Sastry *et al.* (1984) is presented in Table. 5.1. It may be pointed out that the lower part of the Quaternary sequence remains uninvestigated and the only available information is that provided by Chandra and Chowdhary (1969).These workers of the ONGC have given a Pleistocene age to their Jambusar Formation of Ahmedabad - Mehsana, Cambay - Tarapur and Jambusar -

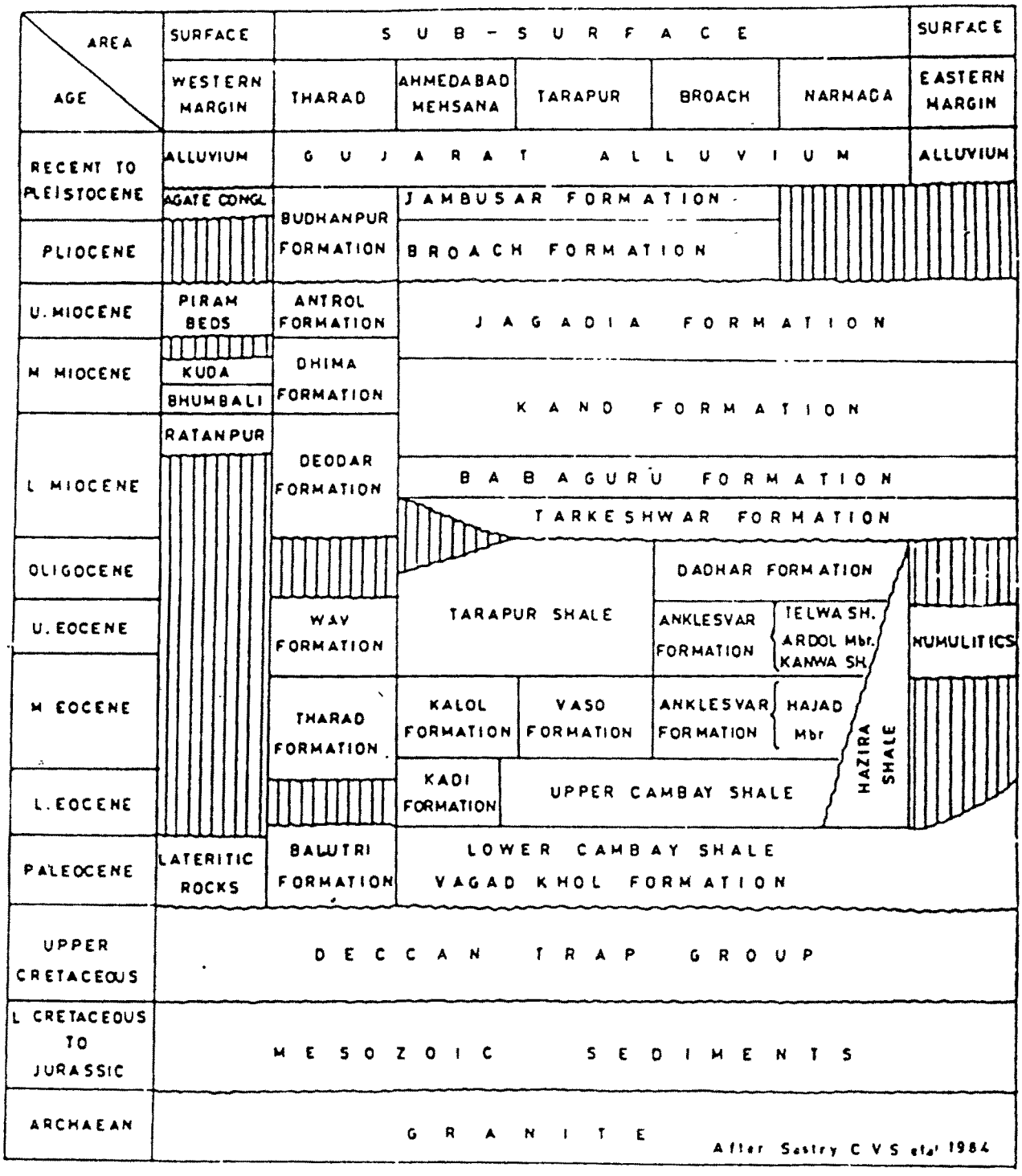

Table 5.1 Generalized Stratigraphic Succession of Cambay Basin

Broach tectonic blocks of Cambay Basin. In the Tharad - Serau block further north, the upper part of Budhanpur Formation has been considered to comprise Lower Pleistocene; or in this formation Pliocene is perhaps gradually changing over to Pleistocene, the entire sequence mostly being fluviatile. In the sub-surface on the western margin of the Cambay Basin in the Dhanduka block (Saurashtra), a conglomerate resting directly over Deccan Trap perhaps represents Lower Pleistocene. In the Viramgam section an undifferentiated sequence resting over the Oligocene Khora Formation could also in part be of Lower Pleistocene age. The agate bearing conglomerates of the coastal areas of Saurashtra and the conglomeratic horizons of the Jhagadia Formation exposed on the Mainland along the eastern margin of the Cambay Basin have been considered as Lower Pleistocene (Merh, 1992).

The base of the huge fluvio-aeolian sequence is a bluish green mottled clay, which is seen exposed in all the major rivers. These clays show well developed rhizocretions and greyish-green drab haloes, indicating sub-aerial activity prior to the deposition of the overlying fluvial sediments. This oldest horizon has been reported by Pant and Chamyal, 1990; Merh, 1991, 1992; Chamyal and Merh, 1992; Merh and Chamyal, 1993; Chamyal, 1995; Khadkikar, *et al.*, 1996. Merh (1992) described them as clays of marine origin deposited during the Middle Pleistocene transgression, stratigraphically comparable with the Miliolites of Saurashtra.

A characteristic feature of these clays is a typical mottled appearance with numerous carbonate tubes, pipes and strings with veins intruding this horizon. These calcrete structures abruptly terminate against the overlying gravels suggesting that they

pre-dated the gravels. As this horizon typically shows development of calcretes, it has to be envisaged that considerable time gap prevailed between the deposition of these clays and that of the overlying gravel; the intervening period gave rise to pedogenetic calcretization. The sequences are exposed in the various river valleys and referred to as Gujarat Alluvium by most workers and Narmada formation by Agarwal (1986), which range in age from Middle Pleistocene to Recent. The sequences, Middle Pleistocene upward, has been better investigated and thus provide ideal exposures on the basis of which a dependable litho-stratigraphy of these could be reconstructed.

LITHOSTRATIGRAPHY OF THE STUDY AREA

The exposed Quaternary continental sediment succession all along the Mahi valley reveals a well preserved record of changes in depositional environment. These changes as well as subsequent depositional events are well marked by the marine, fluvial, fluvio-marine and aeolian sediments. These sediments of different origins are exposed by the present day Mahi channel in the form of high cliffs ranging in height between 5 m - 35 m.

The area between Kadana to Kavi exhibits numerous natural cliff-bank exposures that were studied in detail. Individual litho-sections were measured in the field and marker as well as the comparable lithounits were identified. These exposed successions were than studied in detail to know the lateral as well as the vertical facies variations. On the basis of the relative order of superposition and comparable lithounits overlying and underlying the marker horizon a composite litho-stratigraphy was

prepared (Fig. 5.1; Table 5.2).

The composite lithostratigraphy comprise four formations viz. Rayka formation, Shihora formation, Singrot formation, and Khothiyakhad formation. The Rayka and Shihora formations comprise fluvial sediments whereas the Singrot formation mainly consists of aeolian sediments. The Kothiyakhad formation is made up of fluvial and estuarine sediments.

The detailed description of the lithostratigraphy is as under :

Rayka formation

The Rayka formation is divided into two members: (a) Vasad member and (b) Bhadarwa member.

These members rest over the basal pedogenised mud (vertisol) horizon. This vertisol at the base of the succession is similar to that of the vertisol horizon underlying the trough cross-stratified conglomeratic lithounit. The horizon is mainly clayey and shows mottling and intense fracturing that has given rise to pseudo-anticlines. The clays are yellowish brown in colour (10 YR 5/4) and range in thickness between 0.5 m to 1 m. Carbonate nodules with sharp margins are common in this unit. The greenish colour drab haloes are also observed.

Vasad member

The Vasad member rests over the basal clays that forms the base of the whole exposed Quaternary succession. It consists of four lithounits and has an average thickness of 8 m - 9 m. The four lithounits identified are as follows:

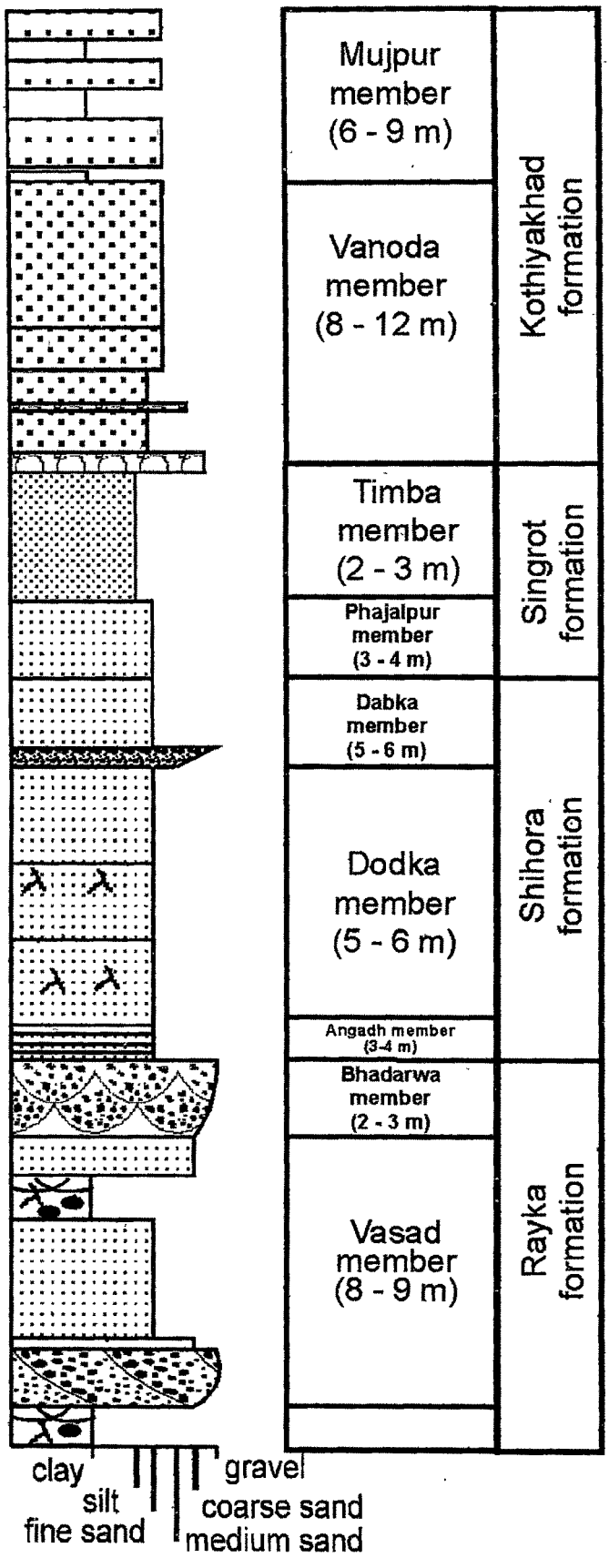

Fig. 5.1 : Composite lithostratigraphy of the Mahi basin

Formation	Member	Lithology	Age	Avg. Thickness (m)
Kothiyakhad formation	Mujpur member	Pedogenised fine silty sand, mud, Horizontally laminated silty sand, Planar Cross-stratified silty sand showing Herringbone structure, Horizontally laminated silt and mud.	5 ka to 3 ka	6-9
	Vanoda member	Weakly pedogenised silty sand alongwith molluscan shells, Horizontally stratified sand, silty sand horizon alongwith molluscan shells, calcrete nodules and intercalation of gravel lens. Trough cross stratified gravel; Planar cross-stratified gravel, Planar cross-stratified coarse sand, Unstratified gravel.		8-12
Singrot formation	Timba member	Dunal sands (stabilized ones)	10 ka * to 6 ka	2 - 3
	Phajalpur member	Loess like silts		3 - 4
Shihora formation	Dabka member	Red (rubified) soil with calcrete nodules, Reddish gravelly sand	51 ka *	5 - 6
	Dodka member	Brown pedogenised and yellowish silty sand	86 ka *to 60 ka*	5 - 6
	Angadh member	Silty sand alongwith calcrete nodules, Alternate silts and sand horizon alongwith calcrete layers		3 - 4
Rayka formation	Bhadarwa member	Trough to planar cross-stratified conglomerate comprising caliche, quartizitic and basaltic clasts.	108 ka*	2 - 3
	Vasad member	Trough cross-stratified sand, Vertisol (Pedogenised fractured mud), Fine silty sand, Horizontally stratified silts and calcrete bands, Planar cross-stratified conglomerate comprising basaltic and caliche clasts.	<200 ka (based on Paleolithic tools)	8 - 9
		Pedogenised mud with rhizocretions and drab haloes (Vertisol).	>240 Ka	<1 - 3

* TL - Dates

Table 5.2 : Lithostratigraphy of Mahi river basin

(i) Planar cross-stratified calcrete gravel/conglomerate, ranges in thickness between 2 m to 2.5 m in the lower reaches, while in the upper reaches, the thickness is usually between 4 m to 5 m. It mainly comprises calcrete clasts alongwith basaltic fragments in the lower reaches, whereas in upper reaches the clasts are dominantly quartzitic. The unit shows varying degree of cementation that increases with the dominance of calcrete clasts. The unit is well exposed at Vasad, Rayka, Poicha and Kadana (Plate 5.1).

(ii) Horizontally stratified sand overlies the planar cross-stratified calcrete conglomerate. This horizontally stratified sand lithounit ranges in thickness between 3 m to 4 m. They are bounded by laterally continuos non-erosive surfaces. The unit shows well developed sub-horizontal calcrete bands.

(iii) Trough cross-stratified sand lithounit that overlies the horizontally stratified sand horizon. The unit mainly consists of fine sand and ranges in thickness between 0.5 m to 1.5 m and is well exposed at Dabka, Vasad, Rayka and Poicha.

(iv) The upper most pedogenised mud (vertisol) horizon overlies the trough cross-stratified sand horizon and ranges in thickness between 1 m to 1.5 m. This clayey horizon shows intense fracturing, mottled nature and well developed pseudo-anticlines (Plate 5.2).

Bhadarwa member

The Bhadarwa member overlies the Vasad member and consists of matrix supported trough cross-stratified calcrete conglomerate. This lithounit is abundant in the succession ranging in thickness between 0.5 m to 3.5 m and is well exposed at

Rayka. It consists mainly of calcrete and quartzitic clasts alongwith basalts and coarse sand, silts and clay as matrix. The amplitude of the trough varies between 1.5 m to 3.5 m and is well exposed at Rayka, Vasad and Bhadarwa. At places the trough cross-stratified unit occurs in association with planar cross-stratified conglomeratic units. The foresets show mean average palaeoflow due SSE-SW.

Shihora formation

The Shihora formation (Plate 5.3) rests over the Rayka formation. It consists of three members : (a) Angadh member, (b) Dodka member and (c) Dabka member.

Angadh member

The Angadh member rests over the Bhadarwa member of Rayka formation. The average thickness of this member varies between 3 m to 4 m and is well exposed at Angadh, Rayka and Poicha. This member comprises alternate fine silt and sand horizons alongwith calcrete layers. The calcrete layers being confined to the fine silty horizons.

Dodka member

The succession of Dodka member consists of two well-developed pedogenised silts with intervening yellowish silt horizon. The thickness of this member ranges between 5 m to 6 m. The pedogenised horizons show yellowish brown (10 YR 5/4) to pale brown (10 YR 5/4) and very pale brown (10 YR 7/4) colours. These show blocky nature, presence of buried root channels, alongwith calcrete nodules concentrated in

Plate 5.1 : Planar cross-stratified conglomerate at Poicha.

Plate 5.2 : Pseudo-anticlines in the vertisols at Rayka.

Plate 5.3 : View of sediment succession at Shihora overlying the Deccan Traps.

Plate 5.4 : View of sediment succession exposed in the right bank at Singrot.

lower portion of the soil profile. These two palaeosols are well exposed at Vasad, Rayka, Poicha, Dodka and Shihora.

Dabka member

This member forms a marker horizon for the exposed Quaternary sediment succession. This marker horizon consists of yellowish red (5 YR 5/6) colour (rubified) pedogenised horizon, ranging in thickness between 5 m - 6 m. This rubified horizon separates the fluvial sediments from overlying aeolian sediments and has a spatial spread, hence acts as a marker horizon between two different depositional environments. The horizon is well exposed at Dabka, Angadh, Vasad, Rayka, Poicha and Shihora. The rubified horizon at places is replaced by a reddish sandy gravel pointing to lateral facies variation.

Singrot formation

This formation is dominantly made up of aeolian sediments resting over the fluvial sequence of the underlying Dabka member of the Shihora formation (Plate 5.4). The Singrot formation is divided into two members: (a) Phajalpur member and (b) Timba member.

Phajalpur member

The member mainly comprises yellowish, structureless fine silty sands and occurs extensively in the Mahi basin ranging in thickness from 3 m - 4 m. The silts form typical steep vertical bluffs, a characteristic feature of loessic silts. These are rich

in carbonate nodules which are dense towards top. It consists dominantly of well sorted fine silts of about 64%, and the actual appearance is "loess-like". Obviously these owe their origin to aeolian environment.

Timba member

The member overlies the "loess-like" silts of Phajalpur member with a break in deposition marked by a palaeosol. It comprised silty-sand and medium to fine grained sands. The thickness of this member varies from 2 m to 3 m. The member shows typical dunal topography. These linearly occurring dunal landforms are well seen near Devpura located on the right bank of Mahi, where the dunes are seen as high as 15 m - 20 m trending due NW (Plate 5.5). In the exposed section this unit shows pedogenesis in the upper portion, which points to their stabilization.

Kothiyakhad formation

The Kothiyakhad formation is the youngest formation mapped in the Mahi basin. Stratigraphically this younger succession overlies the Singrot formation. The formation comprises sediments of mainly fluvial and marine origins and occurs in the alluvial and the coastal-estuarine zones. The Kothiyakhad formation is divided into the following two members: (a) Vanoda member and (b) Mujpur member.

Vanoda member

This member comprises the following five lithounits of coarse and finer sediments :

Plate 5.5 : NW trending stabilized dune at Devpura.

Plate 5.6 : Sediment succession at Vanoda.

(i) Poorly sorted gravel unit forms the base of the fluvial succession and is made up of dominantly quartzitic clasts with some basaltic and granitic pebbles. The thickness of the unit varies between 0.5 m - 1.5 m and is well exposed at Vanoda and Rajupura. The quartzite clasts ranges in size between 5 cm - 18 cm and are well rounded. The matrix is mainly of coarse sand and silts.

(ii) Horizontally stratified sand unit varying in thickness from 1 m - 1.5 m and is well exposed at Rajupura. The unit shows well developed alternate light and dark bands of sand and fine silts. The sand is medium to fine grained and contains mainly quartz.

(iii) Planar cross-stratified sand unit varies in thickness between 1.5 m - 2 m. The sand is dominantly made up of quartz with subordinate amount of basaltic grains, and some reworked calcrete nodules. The foresets show variable dips between 10° - 12° due SW (palaeoflow). The unit at places shows embedded aggregates of fractured mud clasts ranging in size between 0.3 m - 0.4 m in diameter.

(iv) Planar to trough cross-stratified matrix supported gravel which occur in the upper parts of the lithounit at Rajupura. The clasts are finer as compared to the underlying poorly sorted gravels.

(v) Silty-sand (alongwith molluscan shells): This unit forms the top of the Vanoda member. The thickness of this unit ranges between 6 m - 7 m, and are exposed at almost all places, but the occurrence of molluscan shell horizon is not common. The silty sand unit at the top shows weak pedogenesis. This unit at places shows intercalation of gravelly-cobbly lenses ranging in thickness between 0.3 m -

0.4 m. It comprises 2-3 lenses of 23 cm - 25 cm molluscans shell beds. This is well exposed at Vanoda. The unit does not show any well developed internal stratification, but due to erosion it appears as stratified unit (Plate. 5.6).

Mujpur member

This member comprises sediment succession made up of mainly marine or fluvio-marine sediments (tidal/estuarine) deposited during same depositional event and are comparable with the fluvial sediments of Vanoda member.

The Mujpur member consists of the following lithounits :

(i) Horizontally laminated silty sand-mud unit, showing fine alternate laminations of mud and very fine silty-clays varying in thickness between 0.5 m - 0.75 m and exposed at Singrot, Mujpur and Kothiyakhad. It shows dark brownish black colour. In the downstream this unit at places is replaced by horizontally laminated sand. The thickness of the individual laminae varies between 0.5 cm - 0.25 cm.

(ii) Planar cross-stratified sand unit that is well exposed at Kothiyakhad. This unit at places in downstream shows well developed herringbone structure marked by bi-directional planar foresets. The thickness of this lithounit varies between 0.7 m - 1 m.

(iii) Horizontally laminated sand unit, varying in thickness between 0.4 m - 0.5 m. The laminations are well exhibited by the occurrence of alternate dark and light bands of sand and fine silty-clay.

(iv) Mud lithounit showing well developed laminations, marked by alternate laminae of mud and very fine silts. At places the unit is well characterized by mud flasers

marking an undulatory surface with the underlying units.

(v) Weakly pedogenised silty-sand unit forms the top of the succession. The thickness of the unit varies between 0.4 m - 0.5 m. In the upper portion, this unit shows pedogenic features such as buried rootlets, burrows and millimeter-sized powdery calcrete nodules.

LOCALITYWISE DESCRIPTION

The Mahi river basin provides well exposed Quaternary sediment successions all along its valley. The exposed litho-sections occur in the form of high cliffs (5 m - 35 m). Representative litho-sections were measured and studied in detail (Fig. 5.2) to build the composite lithostratigraphy on the basis of the relative order of superposition.

The detailed descriptions of the measured litho-sections are as under:

DAHEVAN SECTION

This section is located on the right bank of Mahi river and has a cliff height of about 14 m. The section comprises sediments of Dabka member of Shihora formation (7 m), overlain by Phajalpur member (6 m) and Timba member (1 m) of Singrot formation (Fig. 5.3). The base of the Dabka member is made up of silty-sands showing well developed troughs pointing to a channel-fill morphology. The alternate beds of sand and silty-mud occur parallel to the troughs (Plate 5.7). The maximum channel width visualized by the troughs is about 12 m in length and 1 m in depth. The channels show average palaeo-current direction due SSW. The 3 m thick silty sand horizon is

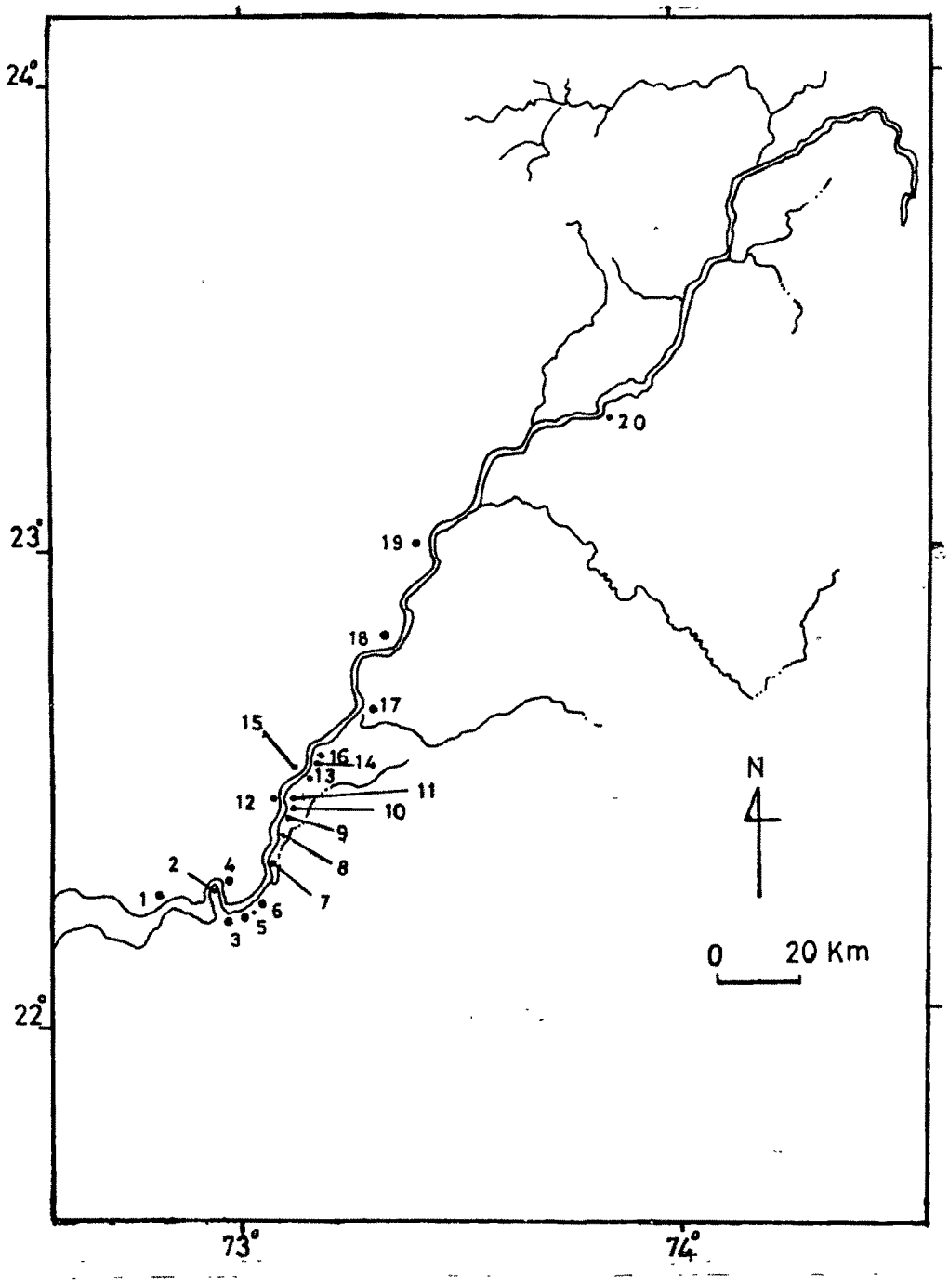

Fig. 5.2 : Locations of the sections investigated.

1. Dahevan
2. Mohommodpura
3. Dabka
4. Kothiyakhad
5. Mujpur
6. Jaspur
7. Singrot
8. Angadh
9. Phajalpur
10. Rayka
11. Dodka
12. Rajupura
13. Bhadarwa
14. Wankaner
15. Sili
16. Poicha
17. Shihora
18. Timba
19. Vanoda
20. Kadana

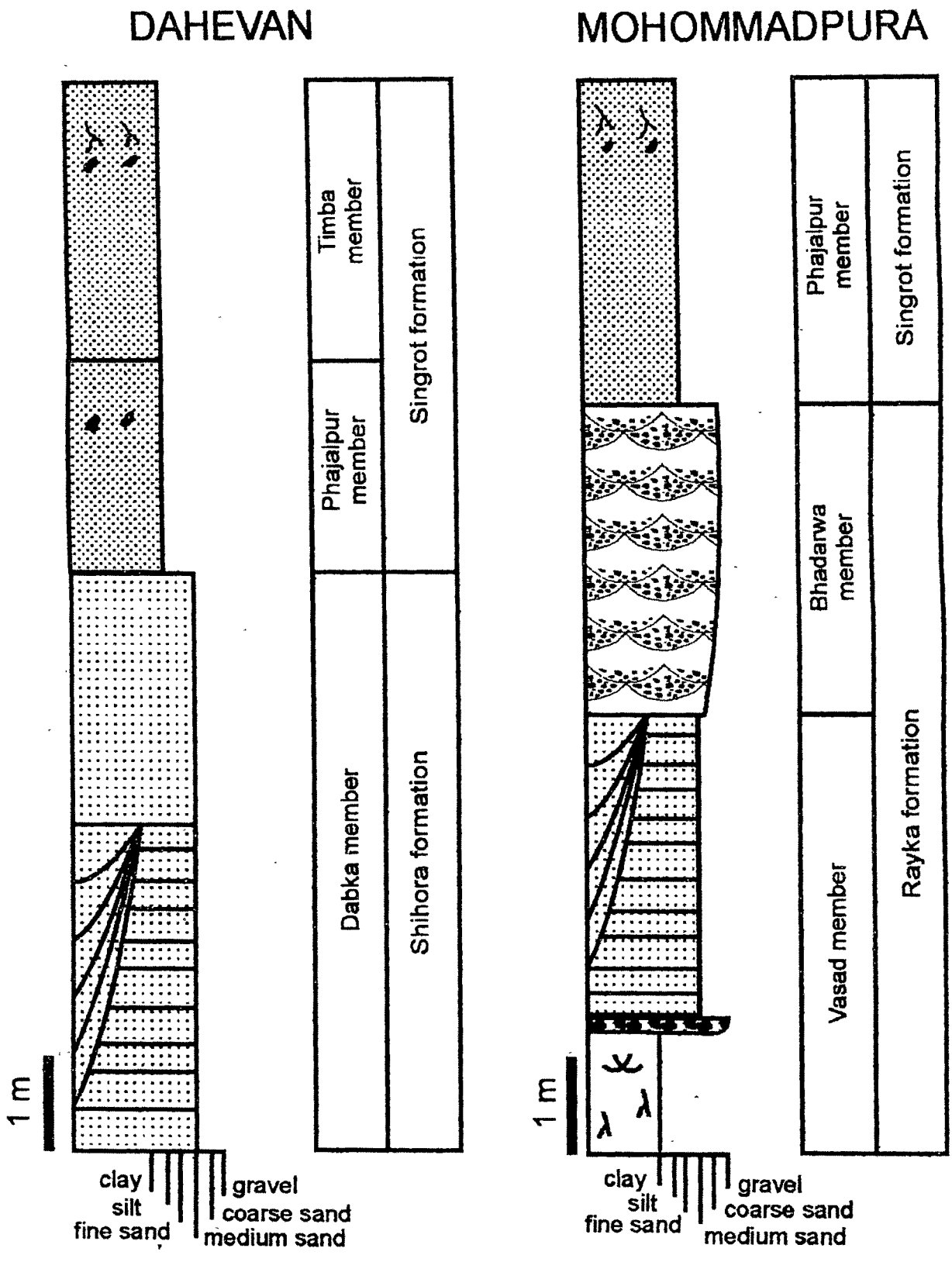

Fig. 5.3 : Lithosections at Dahevan and Mohommadpura

Plate 5.7 : Channel-fill deposits at Dahevan.

Plate 5.8 : Sediment succession at Mohammadpura.

overlain by a reddish palaeosol, which is capped by 6 m thick Singrot formation, consisting of 2.5 m thick "loess-like" silts of Phajalpur member and 3.5 m thick sands of Timba member.

MOHOMMADPURA

This section (11 m) is located on the left bank near the mouth of the present day Mahi river (Plate 5.8). The exposed sediment succession rests over the pedogenised mud horizon (vertisol) of ~1.5 m (base not exposed). The basal portion of the succession comprises 3 m thick horizontally stratified sand of the Vasad member of Rayka formation (Fig. 5.3). The horizontally stratified sands are marked by sub-horizontal calcrete layers and at places show channel-fill structures. This is overlain by 3 m - 3.5 m thick trough cross-stratified unit of Bhadarwa member of Rayka formation. This lithounit comprises mainly calcrete clasts with sand as matrix and has an erosional contact with the underlying horizontally stratified unit. The aeolian unit of 3.5 m - 4 m of the Singrot formation overlies the Rayka formation. This aeolian unit consists of 2 m thick Phajalpur member, showing pedogenesis in its upper part, overlain by 1.5 m - 2 m thick Timba member. The Shihora formation is absent.

DABKA SECTION

This section is located upstream of the Mohommadpura (Fig. 5.4). The cliff of 15 m is exposed on the left bank of river, of which the basal 2 m succession is covered by the scree material. The exposed succession shows well developed 3 m thick medium to fine silty-sand horizon of red (rubified) palaeosol (Plate 5.9). This horizon has been

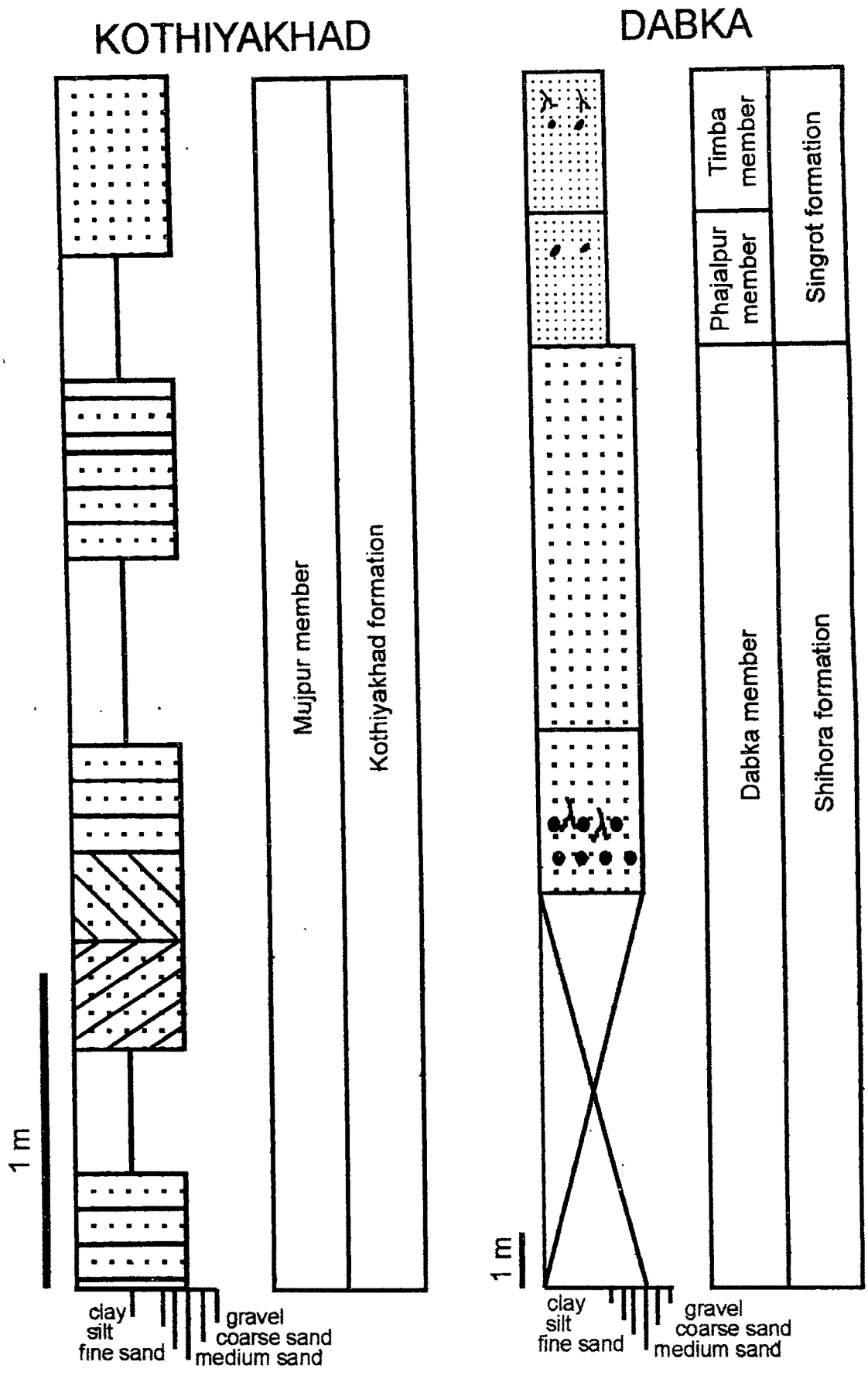

Fig. 5.4 : Lithosections at Kothiyakhad and Dabka

Plate 5.9 : Rubified silts at Dabka.

Plate 5.10 : Sediment succession at Kothiyakhad.

considered as a marker for intra- and extra-basinal correlations (Pant and Chamyal, 1990). The horizon is yellowish red (5YR 4/6) and is calcretized. The base of the horizon shows high concentration of calcrete nodules ranging in size from 1.5 mm to 2.5 mm in diameter. The sediment size becomes coarser towards the top alongwith the decreasing concentration of calcrete nodules. In the upper part the sediments are mainly silty-sand and show well developed pedogenic features like buried rootlets, rhizocretions and burrows that are dark brownish-black in colour. This is overlain by 5 m - 6 m horizontally stratified silt horizon with sub-horizontal calcrete layers. The Singrot formation overlies the Shihora formation and comprises 3 m thick "loess-like" silts (Phajalpur member) that shows well developed pedogenised horizon at the top alongwith scattered calcrete nodules. The top is marked by 1 m thick dunal sands of Timba member.

KOTHIYAKHAD SECTION

This section is located in the lower reaches on the right bank of the river near Kothiyakhad in the present day estuarine zone of the Mahi basin (Fig. 5.4). The 3.7 m - 4 m thick sediment succession represent Mujpur member of Kothiyakhad formation (Plate 5.10). The base is not exposed and a 0.4 m thick horizontally laminated sand forms the base of the succession. The laminations are marked by dark and light bands. The thickness of individual laminae varies between 0.5 cm - 0.25 cm. This is overlain by 0.3 m thick mud. This unit is characterized by mud flasers marking an undulatory surfaces with the underlying unit. The 1 m thick cross-stratified sand horizon overlies this unit, that shows well developed planar foresets showing bi-directional

(herringbone) structure. The 0.7 m thick mud horizon overlies this unit. It is overlain by 0.5 m thick horizontally laminated sand, followed by 0.4 m thick mud showing weak pedogenesis. The sequence is finally capped by medium to coarse silty-sand horizon of about 0.5 m.

MUJPUR SECTION

This lithosection is located on the left bank of the Mahi river. The exposed section of about 6 m shows alternate units of mud and silt (Fig. 5.5). This section is a type section of Mujpur member of Kothiyakhad formation. The base is not exposed. The 0.75 m - 1.6 m thick laminated mud forms the base of the succession. This lithounit shows well developed horizontal laminations, and 0.25 m thick sand lenses. The 0.75 m thick medium to fine grained sand that overlies this unit shows weak pedogenesis. This is overlain by 0.5 m thick horizontally laminated mud. Alternating layers of silty-sand and mud of 1.2 m overlie it. The silty-sand layers show average thickness of about 20 cm - 30 cm, while the mud are 15 cm - 20 cm thick. This is overlain by 0.5 m thick laminated mud horizon, which is overlain by 1 m thick silty sand. Again 0.9 m thick laminated mud horizon overlies this silty sand. Finally the succession is capped by 0.5 m thin sand showing well developed soil unit.

JASPUR SECTION

The section is located on the left bank of the Mahi river in the lower reaches. The cliff height is of about 14 m (Fig 5.5). The lower portion of the succession comprises 3.5 m thick Dabka member of Shihora formation, overlain by 6 m thick

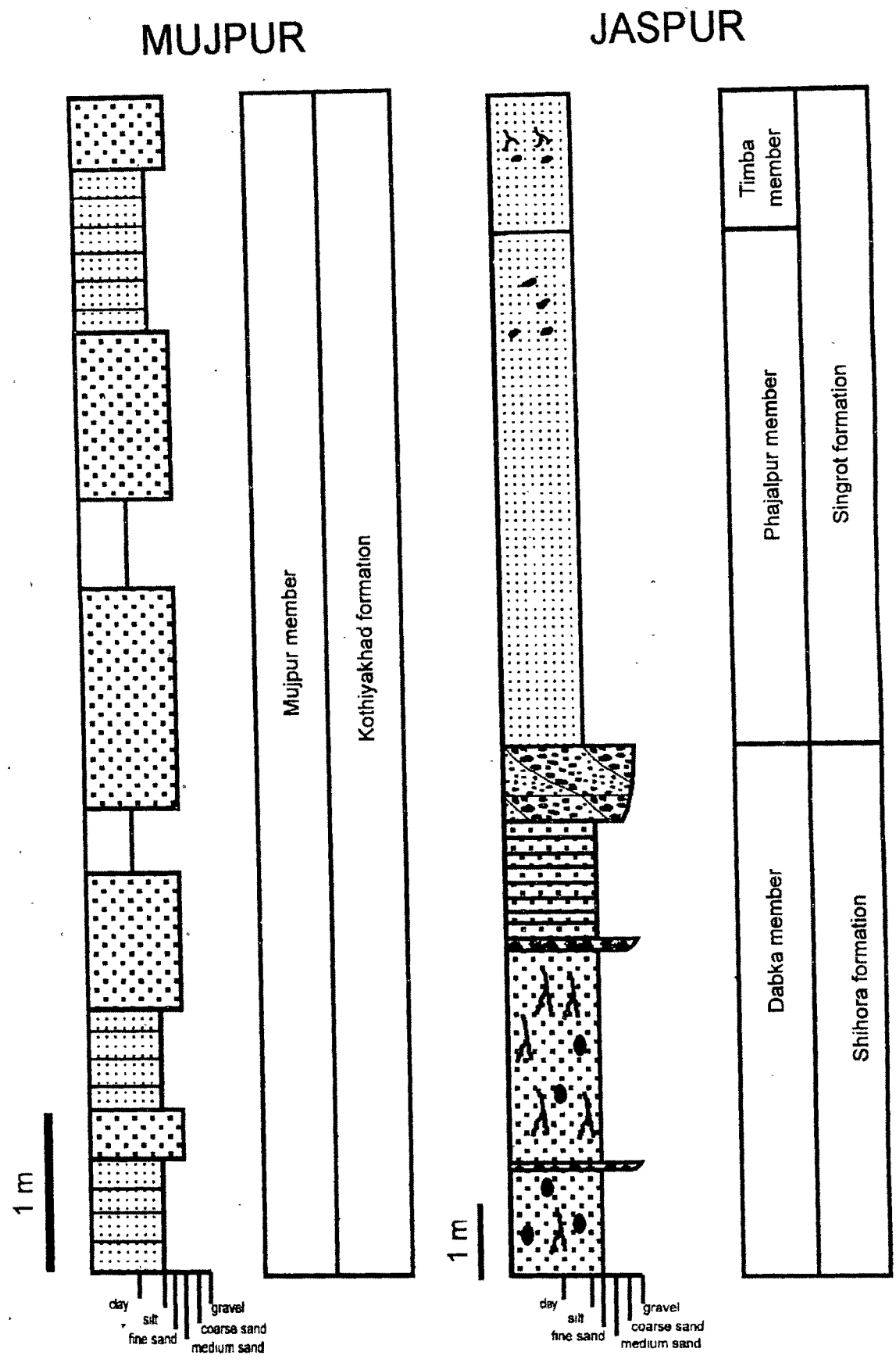

Fig. 5.5 : Lithosections at Mujpur and Jaspur

Phajalpur and Timba member of Singrot formation. The Dabka member comprises 3.5 m thick rubified soil horizon, that shows intercalation of gravel lenses of about 0.4 m thick. This is overlain by horizontally stratified silts comprising sub-horizontal calcrete layers. The 1 m thick gravel horizon at places shows planar cross-stratification, and comprises mainly calcrete clasts ranging in size between 0.4 cm - 0.6 cm.

SINGROT SECTION

This section is located on the right bank of Mahi river, 20 km west of Baroda (Fig. 5.6). The section shows excellent exposures of aeolian deposits, hence named as Singrot formation. The exposed cliff has a height of about 15 m. The horizontally stratified sand alongwith sub-horizontal calcrete layers of Vasad member form the base of the exposed succession at Singrot. This is overlain by 1.5 m - 2 m thick trough cross-stratified calcrete conglomerate of Bhadarwa member. The gravel shows undulatory erosive surface in relation to the underlying unit. These two horizons of Rayka formation are overlain by 3 m thick silty sand over which lies 1.5 m - 2 m thick red soil horizon of Dabka member of Shihora formation. The horizon shows less concentration of calcrete nodules at the base. The "loess-like" silt horizon of Phajalpur member overlies the Dabka member. The horizon is structureless, shows well developed vertical bluffs. At the top of this horizon slight pedogenesis is seen, and also weakly developed calcrete nodules are noticed. The succession is finally capped by 1.5 m thick dunal sands of Timba member.

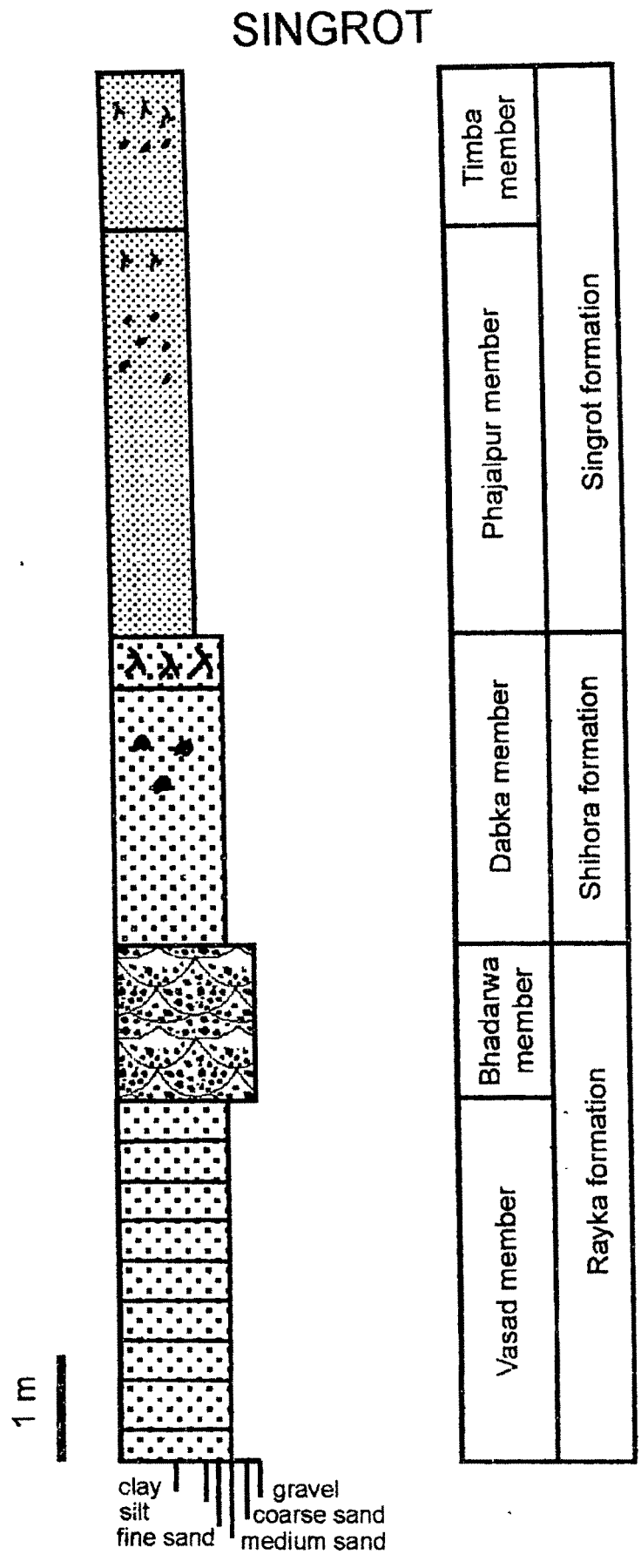

Fig. 5.6 : Lithosection at Singrot

ANGADH SECTION

The section is located 4 km south of Vasad on the left bank of Mahi river. The cliff has a height of about 15 m (Fig. 5.7). The succession rests over the basal pedogenised mud (vertisol) over which rests 1 m thick planar cross-stratified calcrete conglomerate. This unit of Vasad member of Rayka formation shows erosional contact and is made up mainly of calcrete clasts alongwith some basaltic fragments. This is overlain by 1 m thick weakly pedogenised silty horizon which in turn is overlain by horizontally stratified silty-sand horizon of about 4 m thick Angadh member of Shihora formation. The stratification is marked by alternate bands of yellowish colour silty-clay (1 cm - 1.5 cm) and silty-sand (1.5 cm - 2 cm), alongwith calcrete bands confined to the silty-sand layers. The Dabka member of about 5 m overlies the Angadh member and comprises 1.5 m thick silty-sand unit. The rubified horizon (3.5 m) shows 0.5 m thick intercalation of sandy-gravel horizon. The gravel consists mainly of calcrete clasts (1 cm - 1.5 cm) alongwith some basaltic fragments (0.5 cm - 0.75 cm). This is overlain by 3 m thick Singrot formation, made up of 1.3 m thick "loess-like" fine silts of Phajalpur member and capped by 1.75 m thick dunal sands of Timba member.

PHAJALPUR SECTION

This section is located on the left bank of the Mahi river, 23 km northwest of Baroda. The sediment succession comprises 6 m thick Rayka formation, overlain by 8 m thick Singrot formation (Fig. 5.7). The Rayka formation consists of 5 m thick Vasad member made up of 1.5 m thick horizontally stratified sand comprising sub-horizontal calcrete bands. This is overlain by 1 m thick vertisol horizon. This vertisol

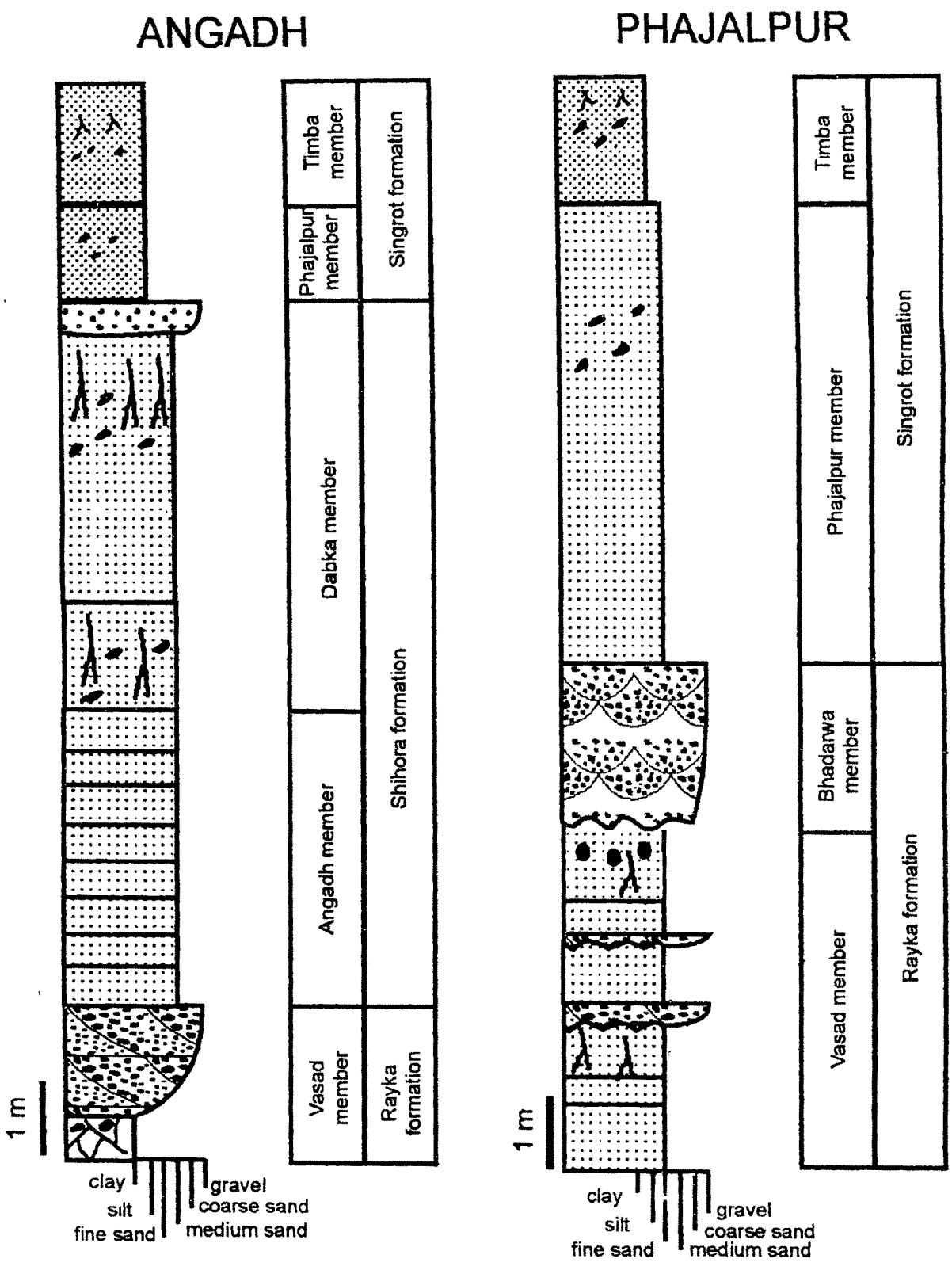

Fig. 5.7 : Lithosections at Angadh and Phajalpur

horizon shows well developed drab-haloes. The gravelly unit of 0.25 m thick overlies the vertisol unit. This is overlain by 1.5 m thick horizontally stratified sand that shows intercalation of 0.15 m thick gravel lens. The top of the Vasad member is marked by 1 m thick mottled, intensively fractured vertisol horizon. The 2 m thick trough cross-stratified conglomerate of Bhadarwa member overlies the Vasad member. The gravels are dominated by calcrete clasts alongwith some basaltic fragments and is overlain by 8 m thick Singrot formation. The Singrot formation comprises 7 m thick "loess-like" silts of Phajalpur member. The top of the succession is marked by 1 m thick dunal sands of Timba member.

RAYKA SECTION

This section is located 26 km NW of Baroda, on the left bank has a cliff height of about 34 m (Fig. 5.8). The section is one of the best exposed sections in the Mahi basin. The section exhibits complete depositional sequence, therefore considered as type section (Plate 5.11). The succession rests over a 1 m thick pedogenised vertisol horizon. At Rayka the vertisol is well developed and shows a yellowish brown (10 YR 5/4) to brown (7.5 YR 5/4) colour. The clays are highly fractured, mottled and show well developed slickensides along the fracture planes. Greenish colour drab haloes are very common. The Rayka formation overlies this basal vertisol and comprises the Vasad and Bhadarwa members. The Vasad member consists of 2 m thick planar cross-stratified calcrete conglomerate showing palaeo-direction due SSE to SSW. This lithounit is made up of smaller calcrete clasts (1.5 cm - 2 cm in diameter) alongwith basaltic fragments, and the matrix is dominated by fine quartz sand and mica flakes.

RAYKA

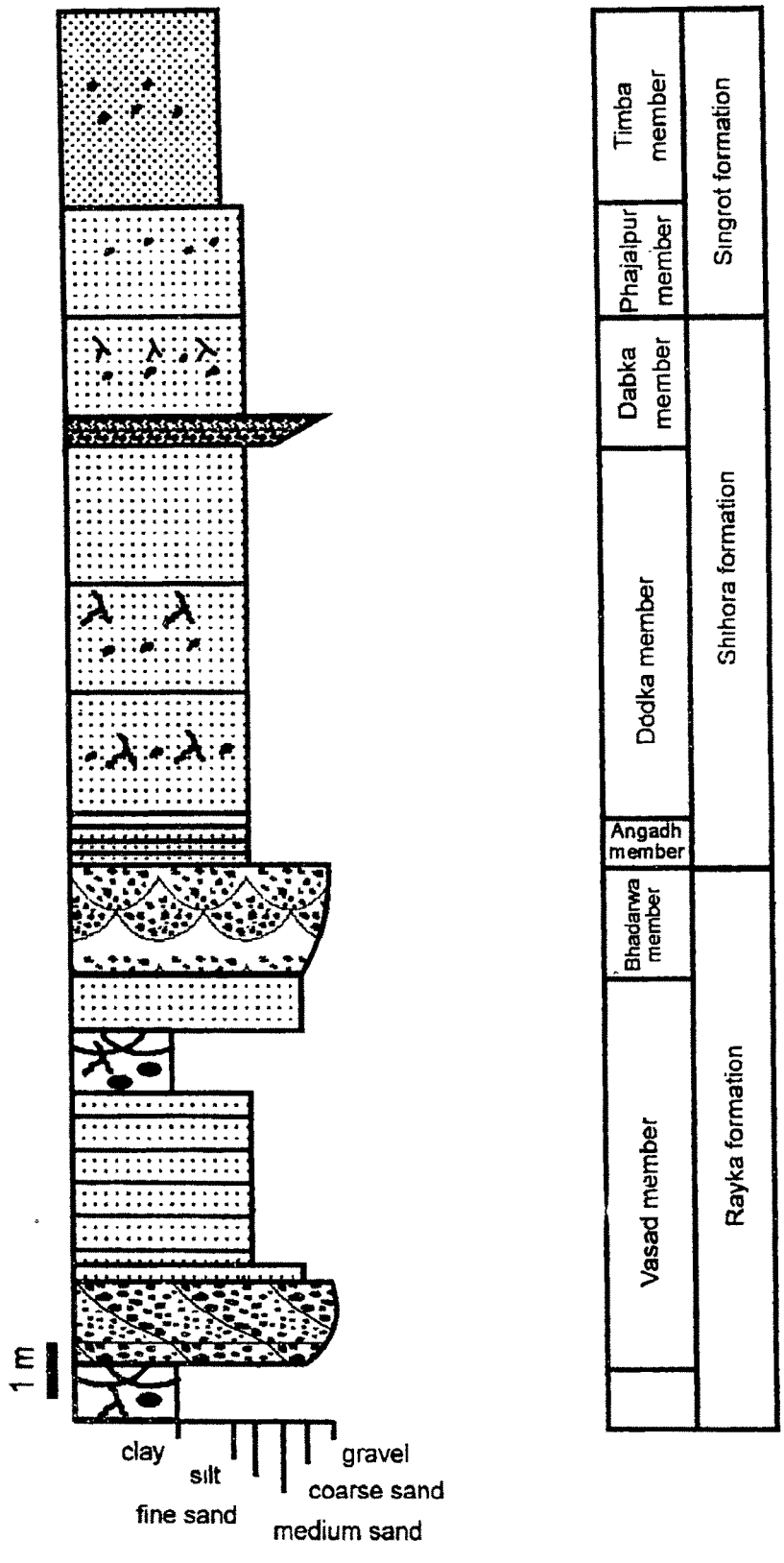

Fig. 5.8 : Lithosection at Rayka

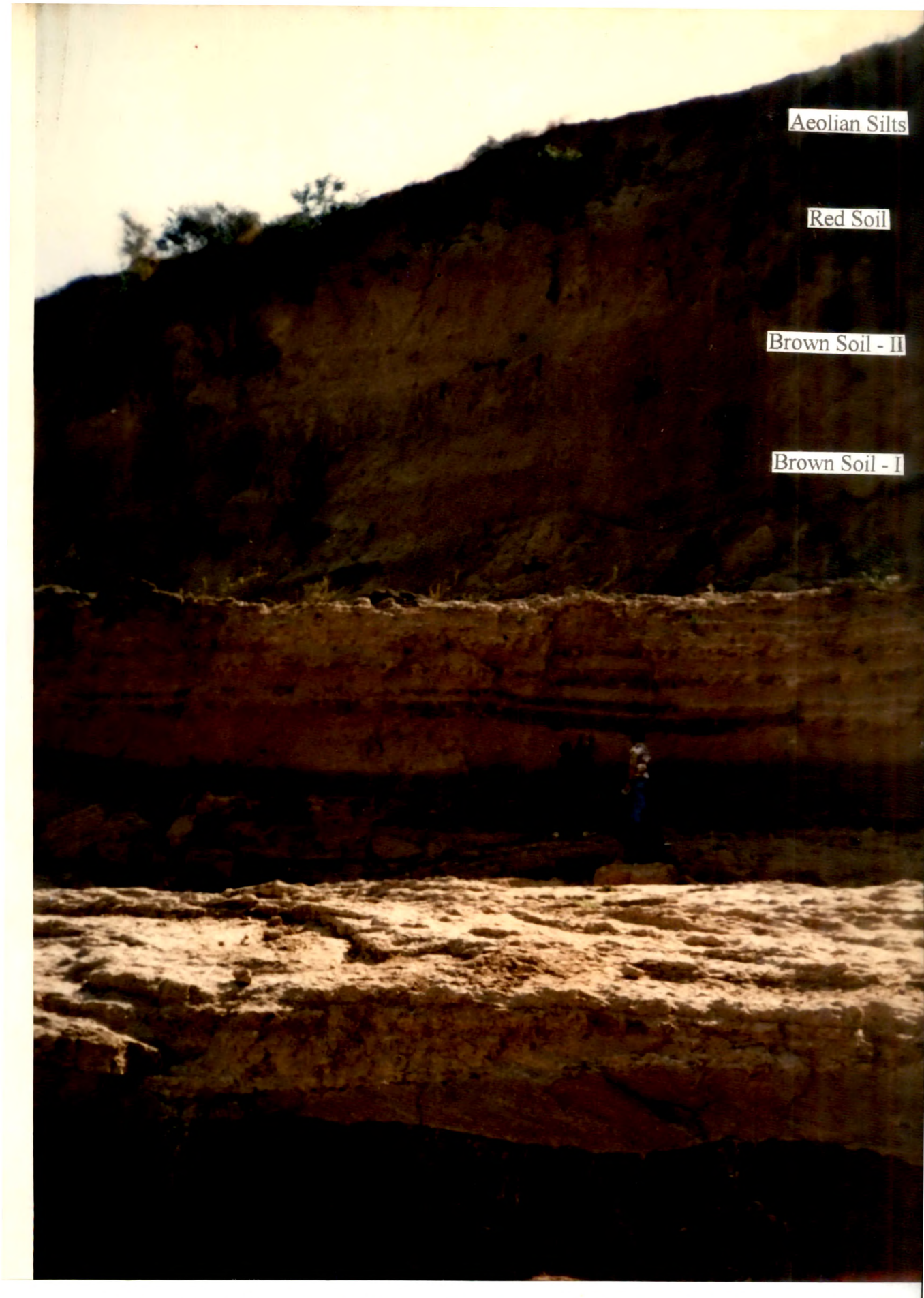

Plate 5.11 : The most complete sediment succession at Rayka showing interlayered cross stratified conglomerates, sands, silts and palaeosols.

The clasts of this unit are moderately well sorted. This is overlain by horizontally stratified silty-sand unit, which shows sub-horizontal calcrete layers. The calcrete layers range in thickness between 15 cm - 20 cm and show folding and warping. A vertisol horizon ranging in thickness from 0.5 m - 1.5 m overlies the horizontally stratified sand lithounit. The vertisol is highly fractured and shows pseudo-anticlines. It contain sub-rounded to rounded calcrete nodules ranging in size between 5 cm - 6 cm in diameter. This is overlain by 1 m thick trough cross-stratified sand horizon marked by 1 m deep shallow channel of about 10 m - 15 m width. The foresets dip by 18° - 19° and show palaeocurrent direction due SSE-SSW. The 3.5 m thick trough cross-stratified calcrete conglomerate horizon of Bhadarwa member overlies the Vasad member. This semi-consolidated lithounit comprises mainly calcrete fragments, concentration of basaltic fragments are less compared to the underlying planar cross-stratified conglomerate. The matrix is dominantly sand and silt with some mica flakes. The calcrete clasts range in size between 15 cm - 18 cm in diameter. The basal surface is erosive marked by the trough ranging in amplitude between 1.5 m to 3.5 m and 1.5 m to 20 m in width.

The unit laterally extends for more than 500 m and is overlain by 14 m thick Shihora formation consisting of (a) 2 m thick horizontally stratified silty-sand comprising alternate sub-parallel calcrete layers of Angadh member, (b) two silty-sand palaeosol horizons of about 2 m thick each showing yellowish brown (10 YR 5/4) and very pale brown (10 YR 7/4) colours. These are separated by 1.5 m thick silty-sand unit. The palaeosols show concentration of calcretes at the base. This is overlain by

0.5 m thick sandy gravel horizon. The rubified soil horizon of about 3.5 m thick overlies the sandy gravel unit. This rubified soil shows yellowish red colour (5 YR 5/6). The horizon shows pedogenic features like buried root channels, burrows etc. The calcrete nodules show high concentration at the base of this unit and range in diameter between 3.5 cm to 8.5 cm. The succession is finally capped by a 5 m thick aeolian sediments of Singrot formation.

DODKA SECTION

This section is located 2.5 km upstream of Rayka on the left bank and has a thickness of about 15 m. The exposed succession is broadly an extension of Rayka section. The section comprises the Bhadarwa member of Rayka formation, Dodka and Dabka members of Shihora formation and Phajalpur and Timba members of Singrot formation (Fig. 5.9). The succession starts with 1 m thick trough cross-stratified gravel of Bhadarwa member, which is overlain by 7 m thick Dodka member. The stratification is marked by sub-parallel calcretic layers. These bands of calcrete showing high inclination of about 35° due NE, indicating tectonic activity in the area. This is overlain by two well developed palaeosol horizons which are separated by 1 m thick yellowish colour silty-sand horizon. These palaeosols show yellowish brown (10 YR 5/4) and light yellowish brown (10 YR 6/4) colours, and pedogenic features like buried root channels, burrows and concentration of calcrete nodules at the base of the profile. The 4.5 m thick Dabka member comprising sandy gravel horizon, red soil and horizontally stratified silty-clay units overlies the Dodka member. The sandy gravel horizon of

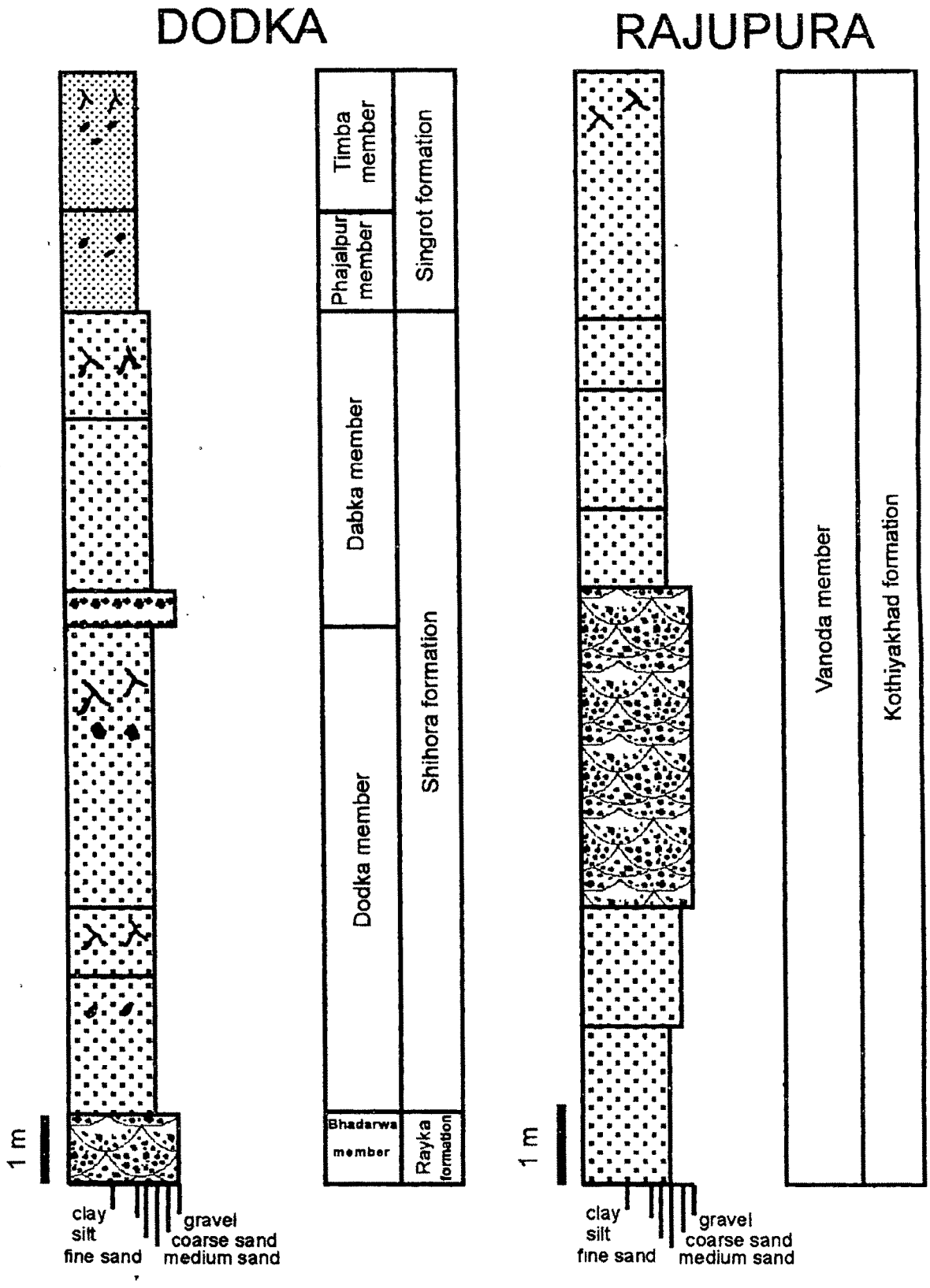

Fig. no. 5.9: Lithosections at Dodka and Rajupura

0.85 m consists mainly of basaltic clasts which are sub-rounded to rounded and ranges in size between 1 cm - 1.5 cm. The overlying pedogenised horizon of about 2.5 m thick shows yellowish red colour (5 YR 5/6). This rubified soil horizon is highly calcified and shows blocky nature, buried root channels and burrows. This is overlain by 1.5 m thick horizontally stratified silty-clay horizon. The clayey layers show reddish brown (5 YR 4/3), mottled and scattered dark brown patches and branching nature of buried root lets. Whereas the silty horizons show yellowish colour and are weakly pedogenised. The 1.5 m thick "loess-like" silts of Phajalpur member overlie the Dabka member. Finally the succession is capped by 2 m thick dunal sands of Timba member.

RAJUPURA SECTION

This section is located on the right bank of the Mahi river 20 km north of Vasad, has cliff height of about 15 m. The base is not exposed. The sediment succession comprise Vanoda member of Kothiyakhad formation (Fig. 5.9). The base of 2 m thick horizontally stratified sand and silts of Vanoda member are overlain by planar cross-stratified coarse sands. The foresets of this horizon show variable dips (10°-12° due SW-SSW). The aggregates of fractured mud of 0.3-0.4 m in diameter are seen embedded in this unit. This is overlain by 4 m - 5 m thick gravels which show poorly developed planar and trough cross-stratification. The clasts are dominantly of quartzite alongwith some clasts of basalts, granites and sandstones. The clasts are sub-rounded to rounded and show fining upward sequence. This is overlain by 2.5 m thick silty-sand unit which in its upper part show horizontal stratification. The sequences is

capped by 2 m - 3 m thick silty-sand that shows weak pedogenesis.

BHADARWA SECTION

The section is located a few kilometers upstream of Dodka on the left bank and has a cliff height of 20 m. The exposed succession shows well developed matrix supported trough cross-stratified calcrete conglomerate, of Rayka formation (Fig. 5.10). The section starts with 8 m thick horizontally stratified sand unit of Vasad member of Rayka formation. This lithounit shows well developed sub-horizontal bands of calcrete. The thickness of this unit varies laterally. This is overlain by 4 m - 5 m thick trough cross-stratified conglomeratic unit representing the Bhadarwa member. This trough cross-stratified unit marks a wide channel indicated by the occurrence of huge trough and show palaeo-flow direction due SW to W. The basal surface of this unit is erosional that has scoured the underlying horizontally stratified sand unit. Another 2 m thick horizontally stratified silty-sand unit of Angadh member overlies this lithounit. This is finally capped by aeolian sediments of Singrot formation made up of 3 m thick "loess-like" silts of Phajalpur member and 1.5 m thick dunal sands of Timba member.

WANKANER SECTION

This section is located 3 km upstream of Bhadarwa. The succession here commences with 9 m thick Vasad member of Rayka formation (Fig. 5.10). The succession from the bottom starts with 3 m thick horizontally stratified sand unit. The stratification is marked by sub-parallel calcrete bands. This is overlain by 1.5 m thick

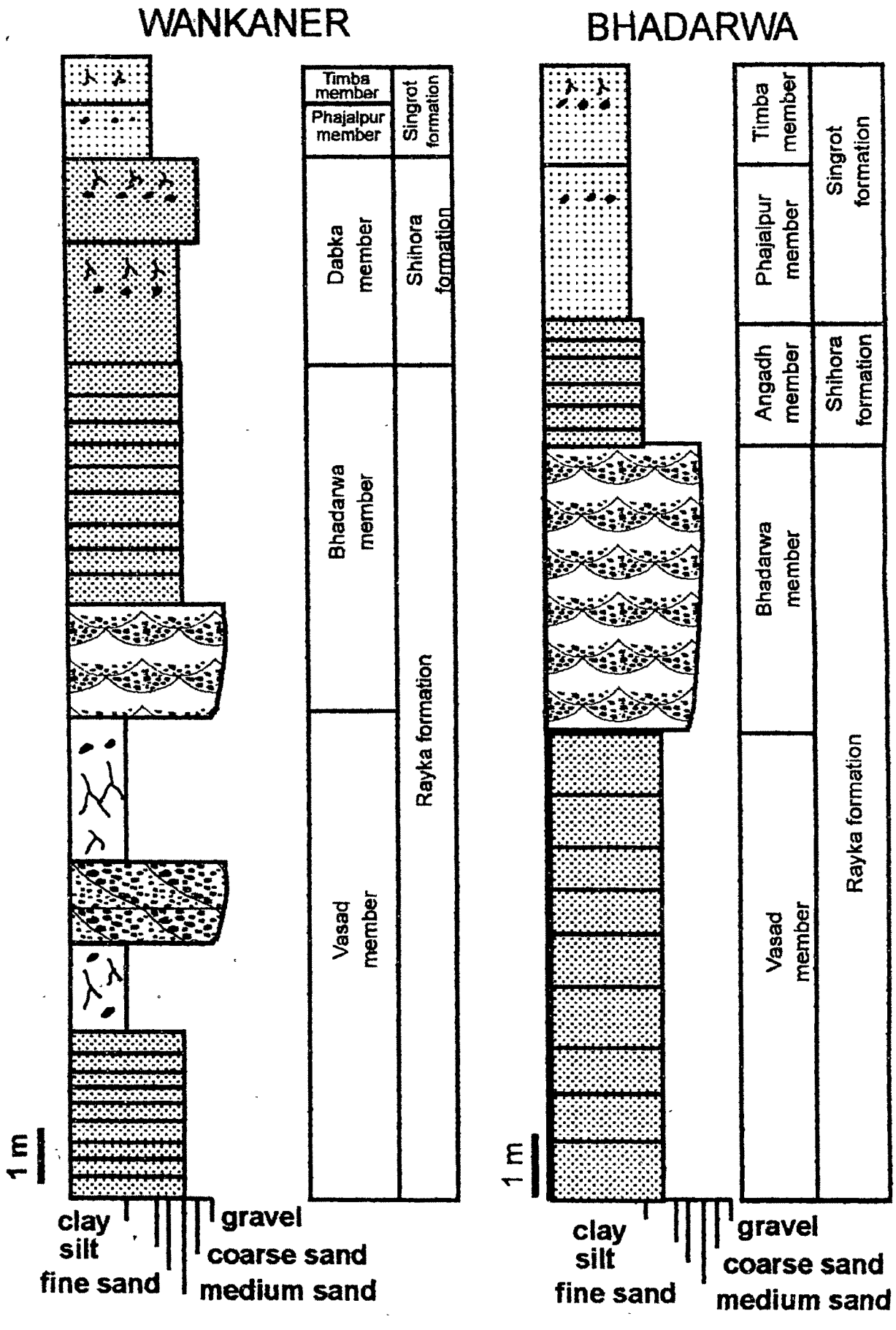

Fig. 5.10 : Lithosection at Wankaner and Bhadarwa

vertisol alongwith the intercalation of 0.45 m thick gravelly sand lens. The 1.5 m thick planar cross-stratified calcrete conglomerate overlies this vertisol horizon (comprising mainly calcrete clasts), show sharp and undulatory erosive contact. This is overlain by 3 m thick well developed pedogenised horizon (vertisol) showing pale brown colour, intense fracturing and contains scattered calcrete nodules showing sharp external boundaries. The 1.5 m - 2 m thick trough cross-stratified calcrete conglomerate of Bhadarwa member overlies this unit. Which shows sharp and erosive contact with the underlying vertisol unit. The erosive nature is marked by 1.5 m deep scours of the troughs. This is overlain by Shihora formation, consisting of 4 m thick horizontally stratified silty-sands of Angadh member and the conglomeratic lithounit. The overlying Dabka member comprises 2 m thick rubified soil and 1.5 m thick yellowish brown colour silty-sands. The succession is capped by 1.5 m - 2 m thick Singrot formation.

SILI SECTION

This section is located on the right bank of the Mahi river (Plate 5.12). The sediment succession has a cliff height of about 20 m. The section comprises 12 m - 13.5 m thick Rayka formation and is overlain by 7 m thick Singrot formation (Fig. 5.11). The Shihora formation is absent. The Rayka formation consists of 9.5 m thick Vasad member and 4 m thick Bhadarwa member. The 1 m thick unstratified, poorly sorted pebbly-cobbly horizon forms the base of the Vasad member. The clasts are dominantly of quartzites ranging between 5 cm - 9 cm in diameter. These quartzitic clasts are well-rounded. The horizon occasionally shows some sub-angular to sub-rounded clasts of basalts and granites ranging in size between 5 cm - 6 cm. This is

Plate 5.12 : Sediment succession at Sili.

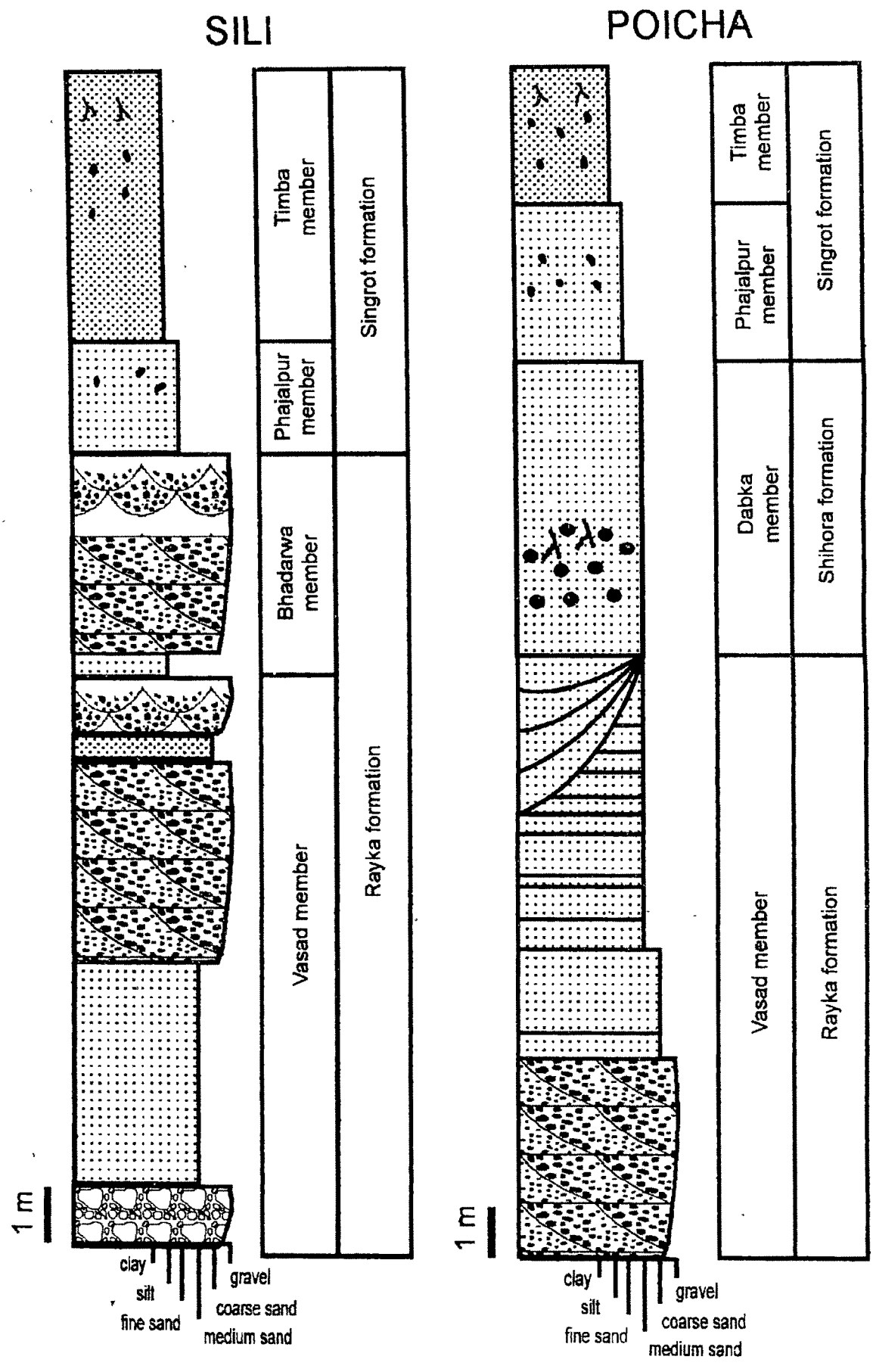

Fig. 5.11 : Lithosections at Sili and Poicha

overlain by 4 m thick horizontally stratified sand lithounit. The stratification is marked by sub-parallel occurrence of calcrete bands; that at places shows warping. The 3.5 m - 4 m thick matrix supported, poorly sorted planar cross-stratified gravel lithounit overlies this horizontally stratified unit. The foresets of the planar cross-stratified gravel shows palaeo-flow WSW to W with varying dips of about 15°-18°. The clasts are dominantly of quartzites alongwith coarse quartz sands and silts as matrix. The overlying 1 m thick calcretized conglomerate is separated by 0.25 m thick coarse sand unit. This conglomerate is mainly made up of calcrete clasts and is overlain by 4.5 m thick Bhadarwa member. This lithounit shows planar stratification at the base where troughs are developed in the upper portion. The trough amplitude is about 0.7 to 4 m. The clasts are dominantly of quartzites alongwith some basaltic fragments. The succession is capped by 2 m thick dunal sands of Timba member of Singrot formation.

POICHA SECTION

This section is located on the left bank near Savli, has the cliff height of about 22 m (Fig. 5.11). The succession comprises 12 m thick Vasad member of Rayka formation, forming the base consists of 3.5 m thick planar cross-stratified conglomerate unit comprising dominantly calcrete clasts alongwith some quartzitic pebbles and medium to coarse grained sand made up of quartz, basalt and granitic fragments as matrix. The foresets of this lithounit show dips ranging between 12°-15° and palaeo-flow direction due SSW-W. The 1.5 m - 2 m thick weakly pedogenised silty-sand horizon separates the overlying 6 m thick horizontally stratified sand unit. This unit is

well demarcated by calcrete bands. At the top of this horizon, well developed troughs representing palaeo-channel fills where amplitude of the troughs ranges between 2 m - 3 m showing palaeoflow due SSW are observed. This is overlain by 3 m thick Dabka member of Shihora formation. The Dabka member comprises buried red (rubified) soil horizon and the Shihora formation is overlain by 6 m thick Singrot formation consisting of 2.5 m thick "loess-like" silts of Phajalpur member and 3 m thick dunal sands of Timba member.

SHIHORA SECTION

The section is located on the left bank, 12 km SE of Dakor near Shihora. The exposed succession of 18 m rests over the agglomeratic trappean basalts (Fig. 5.12). The 3 m thick Vasad member of Rayka formation forms the base. It is made up of 2.5 m thick planar cross-stratified calcrete conglomerate, that shows the palaeo-flow direction due SSE-SSW. The weakly pedogenised silty-clay horizon of about 0.5 m thick overlies this unit. This is overlain by 11 m thick Shihora formation. It consists of 4.5 m thick brownish colour buried palaeosol horizon of Dodka member, which at the base show concentration of carbonate nodules in the lower part of the soil profile. The Dabka member of 6.5 m thick overlies the Dodka member. The Dodka member comprises 5 m thick reddish gravelly sand intercalated with 0.3 m thick coarse sand lenses. The reddish colour is mainly due to coating over the grains, and it is equivalent to the rubified soil unit. This is overlain by 1.5 m thick pedogenised light brown silty-sands. The succession is finally capped by 3.5 m thick aeolian sediments of Singrot formation.

TIMBA SECTION

This section is exposed on the right bank of Mahi near the Timba bridge. The total exposed sediment succession of around 15 m rests over the 5 m - 6 m high cliffs of basaltic basement (Fig. 5.12). The base of the succession comprises 4.5 m thick Vasad member of Rayka formation. The Vasad member consists of 1 m thick planar cross-stratified gravel alongwith intercalation of coarse-sand lenses of 0.3 m thick. The clasts are dominantly of quartzites alongwith some calcrete nodules. The planar cross-stratified gravel is overlain by a 3.5 m thick fine silty-sand horizon, which at the base shows weakly developed vertic features, alongwith intercalation of 0.3 m thick gravelly sand horizon. The Shihora formation overlies this unit of Rayka formation. The 1 m thick horizontally stratified fine silty-sand and silty-clay lithounit of Angadh member form the base of the Shihora formation. This is overlain by 4 m thick Dodka member that comprises two brown colour palaeosol units that are separated by 0.5 m thick yellowish silty-sand horizon. The red (rubified) palaeosol horizon of around 2 m thick of Dabka member overlies the Dodka member. The red soil lithounit shows similar features as seen at the other sites in the lower reaches of the basin. This is overlain by 5 m - 5.5 m thick Singrot formation comprising 3 m thick silts of Phajalpur member and 2 m - 2.5 m thick dunal sands of Timba member. In this area the dunal topography is well preserved all along the valley sides as well as inlandward. The stabilized dunes show average height of about 15 m - 20 m and trend in NW direction.

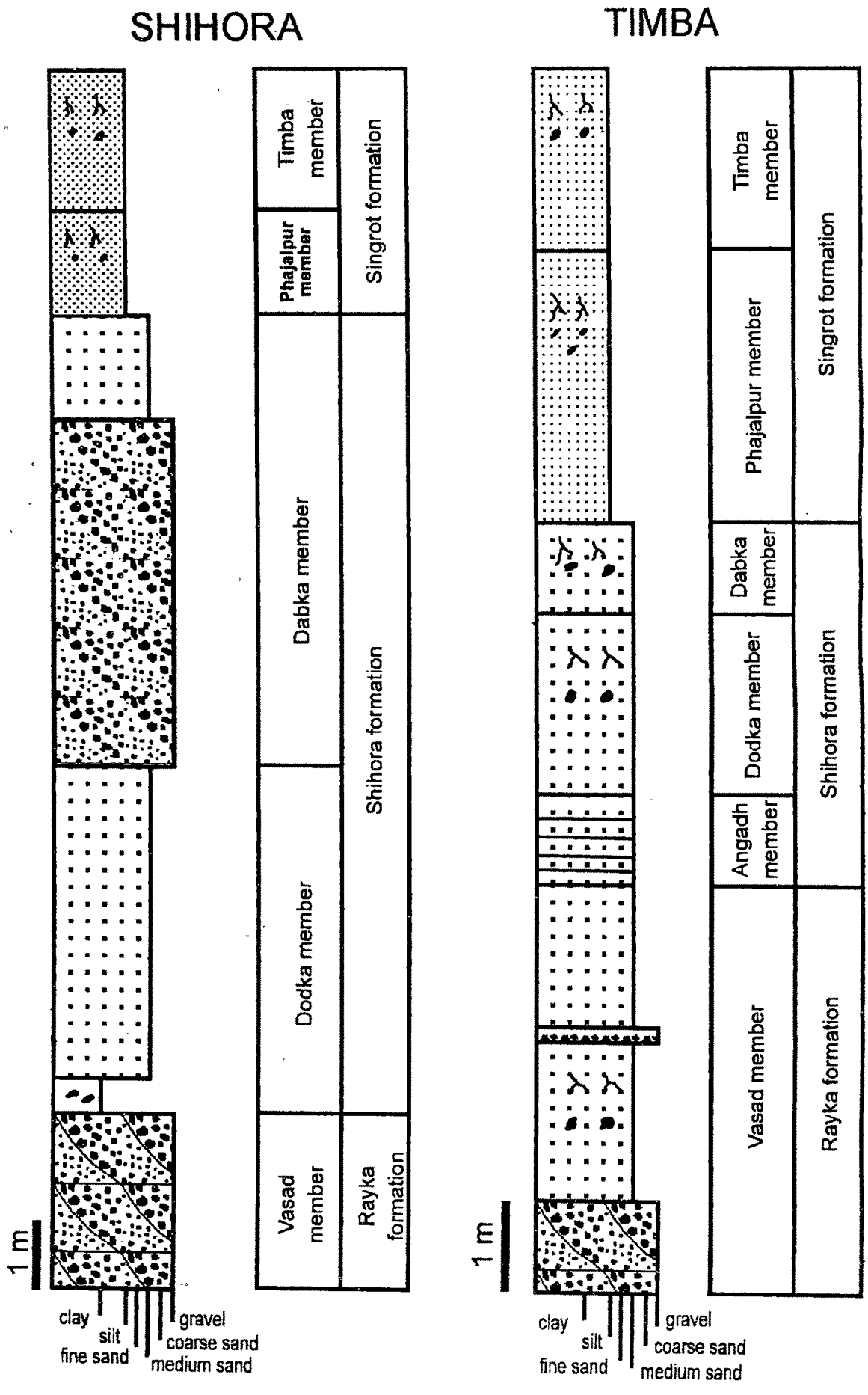

Fig. 5.12 : Lithosections at Shihora and Timba

VANODA SECTION

This section is located about 10 km downstream of Vanakbori on the right bank of Mahi river. The 15 m thick succession represents the younger sequence of the Mahi basin (Fig. 5.13). The succession comprises Vanoda member of Kothiyakhad formation. The succession starts with 1 m thick pebbly-cobbly horizon. which is poorly sorted and show well rounded clasts of quartzites, ranging in size between 10 cm - 15 cm in diameter. The matrix is either a fine sand or silty-clay. This is overlain by 4 m thick fine silty-sand horizon. This unit comprises layers of molluscan shells and intercalation of gravel lenses. The shells are well seen embedded with the silty-sand. The thickness of the shell layers varies between 28 cm - 30 cm. The 2 m thick pedogenised horizon overlies this unit. This unit comprises two layers of molluscan shell varying in thickness between 23 cm - 25 cm. The shell layer occurring at the basal portion are broken and friable, seem to be reworked in nature. The top of this unit shows weakly pedogenised horizon.

KADANA SECTION

This section is located in the rocky uplands on the left bank of Mahi river near Kadana (Fig. 5.13). Here the exposed Quaternary sediment succession occurs in the pockets bounded by the quartzitic hills. The exposed succession of about 15 m - 18 m rests over the quartzites. The succession is made up of 11 m - 11.5 m thick Rayka formation and 3 m - 3.5 m thick Singrot formation. The Rayka formation forms the base of this succession, comprises 7 m thick Vasad member and 4.5 m thick Bhadarwa member. The Vasad member consists of 4 m - 4.5 m thick moderately sorted pebbly-

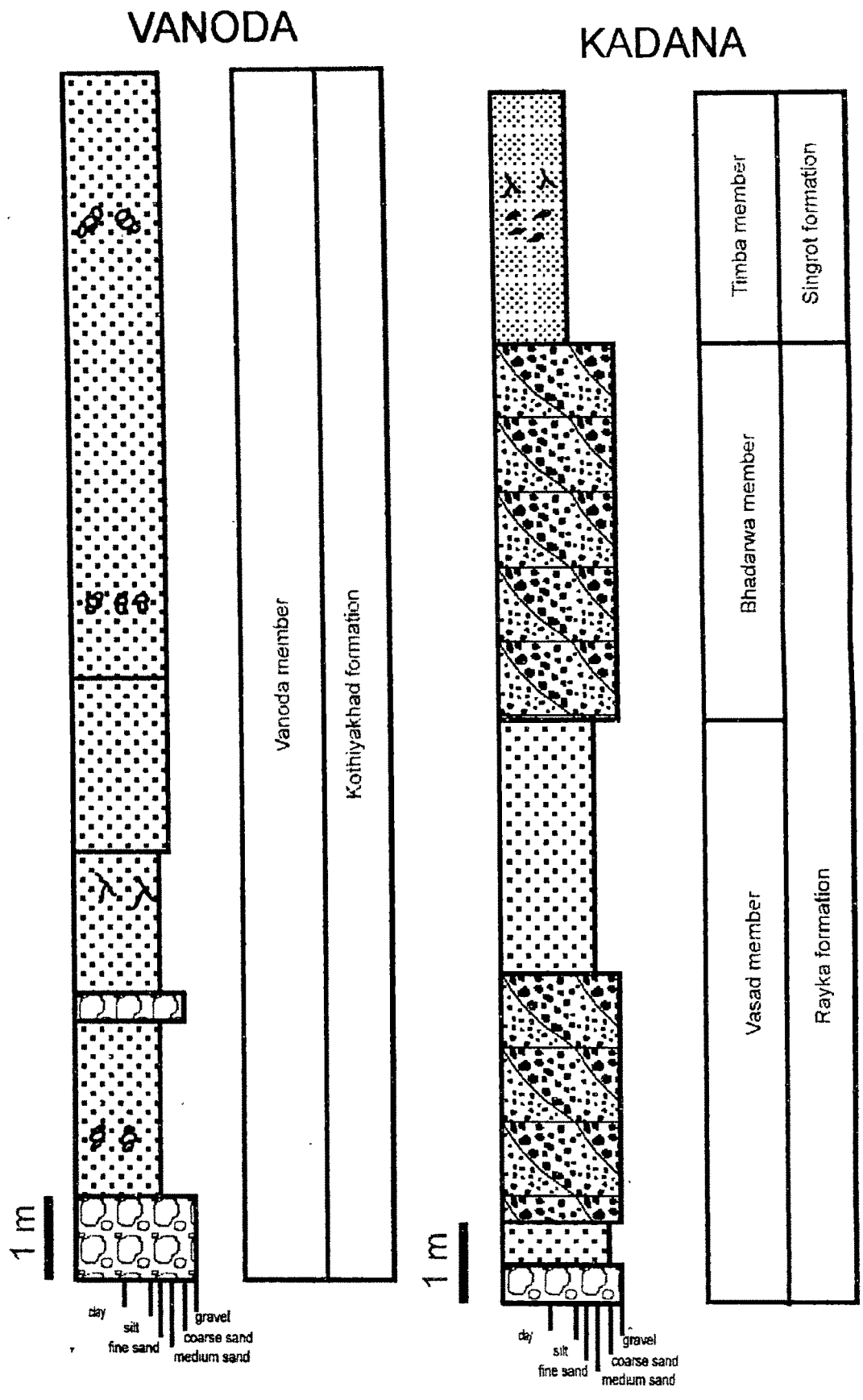

Fig. 5.13 : Lithosections at Vanoda and Kadana

cobbly calcretized horizon and is matrix supported. At the base this lithounit does not show any well developed sedimentary structures, while in its upper portion well developed planar to trough cross-stratification is observed. The cobbles and pebbles are dominantly of quartzite clasts ranging in size between 13 cm - 22 cm, and shows spheroidal, cuboidal and discoidal shape. The foresets of the cross-strata show palaeo-flow direction due SSE-SSW and variable dip ranging between 10°-12°. This lithounit in its upper portion shows some crudely stratified trough cross-stratification. This is overlain by 3 m thick fine silty-sand to silty-clay horizon, which shows shallow troughs of about 1 m in amplitude, and palaeo-flow in SSE direction. The post-depositional tectonic activity particularly the strike-slip movement is well evidenced by the slickensides developed on the face of this horizon. The orientation of the face suggests that the movement must have occurred in the SSW direction. This is overlain by the Bhadarwa member that consists of 4.5 m thick planar to trough cross-stratified unit. The clast size of this unit is finer compared to the underlying planar cross-stratified lithounit of Vasad member. The quartzitic clasts range in size between 8 cm - 10 cm and show SSE-SSW palaeoflow direction. The Timba member of Singrot formation finally caps the sequence.