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INTERNAL STRUCTURE OF SOME TIDAL MEGA–RIPPLES ON A SHOAL IN THE WESTERSCHELDE ESTUARY, THE NETHERLANDS REPORT OF A PRELIMINARY INVESTIGATION

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SUMMARY

Ebb mega-ripples on a sandy shoal in the Westerschelde estuary (SW-Netherlands) were studied in cross-section. The internal structure is dominated by large scale ebb-directed cross-stratification of a particular type showing flood induced erosional and/or depositional modifications. The characteristics betraying the tidal origin of the cross-stratified structure are:

1. Erosional unconformities (diastems) between the successive cross-stratal bundles that build one large scale set.
2. Regular alternations between such bundles and conformably inclined solitary trains of small scale sets containing upslope directed cross-strata.
3. The isolated occurrence of a ± 1 dm-thick coset of small scale cross-strata conformably intercalated between two of the above mentioned bundles.
4. (Sub)horizontal cosets of small scale cross-stratification erosively separating vertically successive large scale ebb-sets.

The above mentioned features confirm the subordinate and rather erosional activity of the flood currents as compared with that of the ebb.

GEO- AND HYDROGRAPHICAL SETTING[2])

In the Westerschelde estuary, the southernmost of the large (several tens of kms. long, few kms. wide) tidal inlets of the North Sea, sandy shoals emerge during ebb. These shoals separate channels in which either ebb or flood currents dominate. The shoal's emerging surface usually is sculptured by large scale and/or small-scale ripples (fig. 1B). Occasionally it is smooth.

The present report concerns the Ossenisse-shoal, S. of Hansweert (figs. 1 and 2) which is flanked on the north by an ebb channel, on the south by a flood channel. Along its narrow northern margin mega ripples directed seaward (= ebb) are found. The southern, broader area is covered with flood mega-ripples. In between a zone is lying with a kind of pot-hole morphology showing troughs more or less circular in plan separated by irregularly-shaped short mega-crests.

Maximum current velocities on the shoal are estimated to be in the order of one meter per second; endeavours will be made to procure more reliable data during future investigations. The magnitude of the tidal range at Hansweert amounts normally to about 4.5 m. During springtide the tidal range is about 5 m. The top of the shoal lies about 1.5 m. below mean high-tide level.

DESCRIPTION OF BED FORMS AND THEIR INTERNAL STRUCTURE

In the following we will briefly discuss the morphology of the ebb as well as the flood mega-ripples. As to the internal structure only ebb-specimens will be dealt with.

The ebb mega-ripples occurring in the northern

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2) Some of the photographs presented have been slightly retouched to enhance contrast necessary for reproduction.

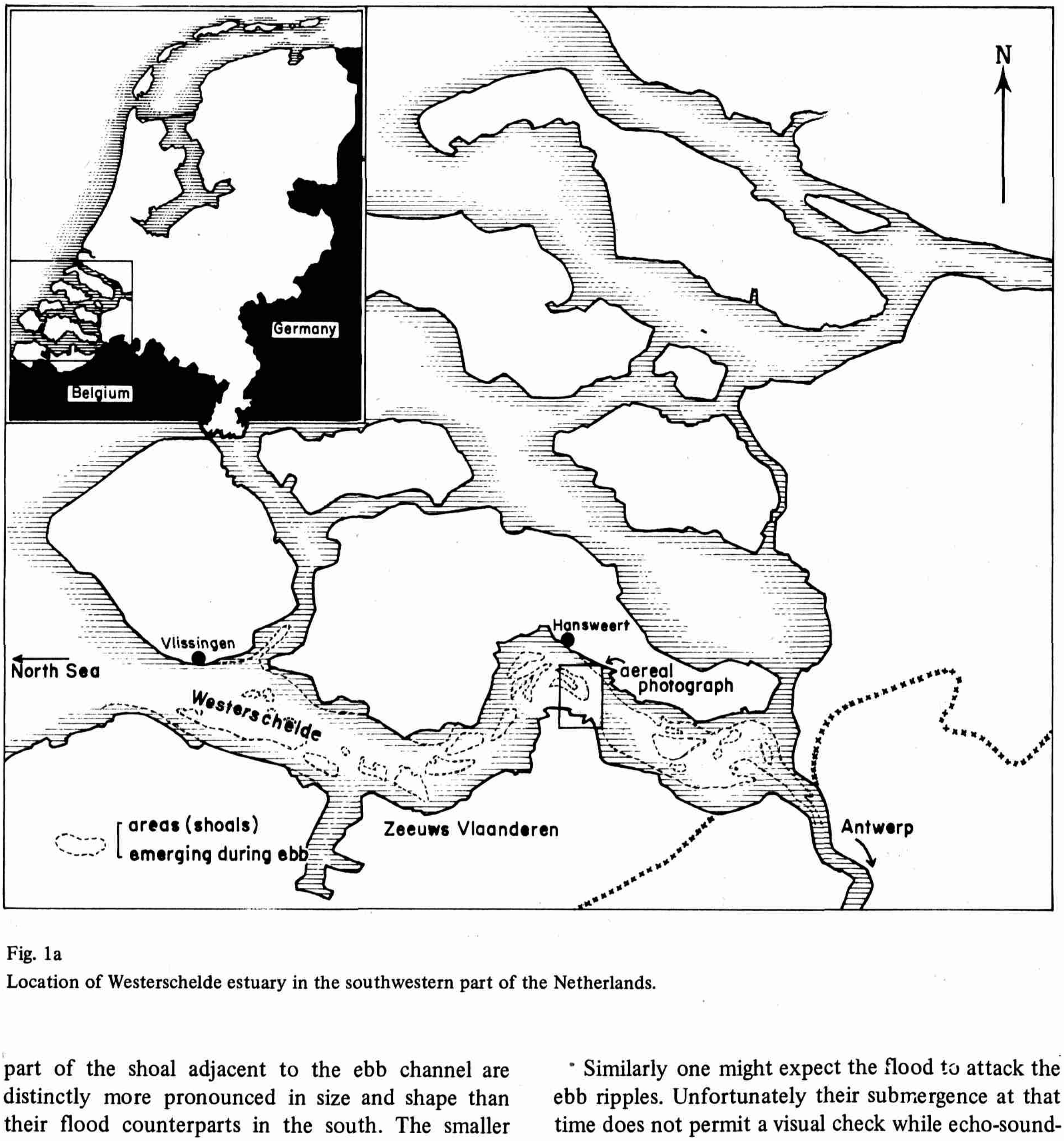

Fig. 1a
Location of Westerschelde estuary in the southwestern part of the Netherlands.

part of the shoal adjacent to the ebb channel are distinctly more pronounced in size and shape than their flood counterparts in the south. The smaller height and wave length of the flood ripples probably are due to lower flood current velocities. In addition ebb currents have erosionally affected the height, sharpness and asymmetry of the flood ripples. At some flood ripples a slight tendency toward reversion of asymmetry (producing a secondary ebb-directed crest superimposed upon the original crest) could be observed. Small-scale ebb ripples were found at the flood ripple's lee side front and upper face.

Similarly one might expect the flood to attack the ebb ripples. Unfortunately their submergence at that time does not permit a visual check while echo-sounding is too inaccurate at this scale. Structural analyses of vertically sectioned ebb mega-ripples, however, showed the validity of such an extrapolation. As can be seen in fig. 3 and 5, numerous internal non-conformities (which may also be called structural diastems), occur between successive bundles of cross-strata in the mega-set. No doubt these diastems result from cessation of supply around slack-water stage often followed by erosion of the mega-ripple-front

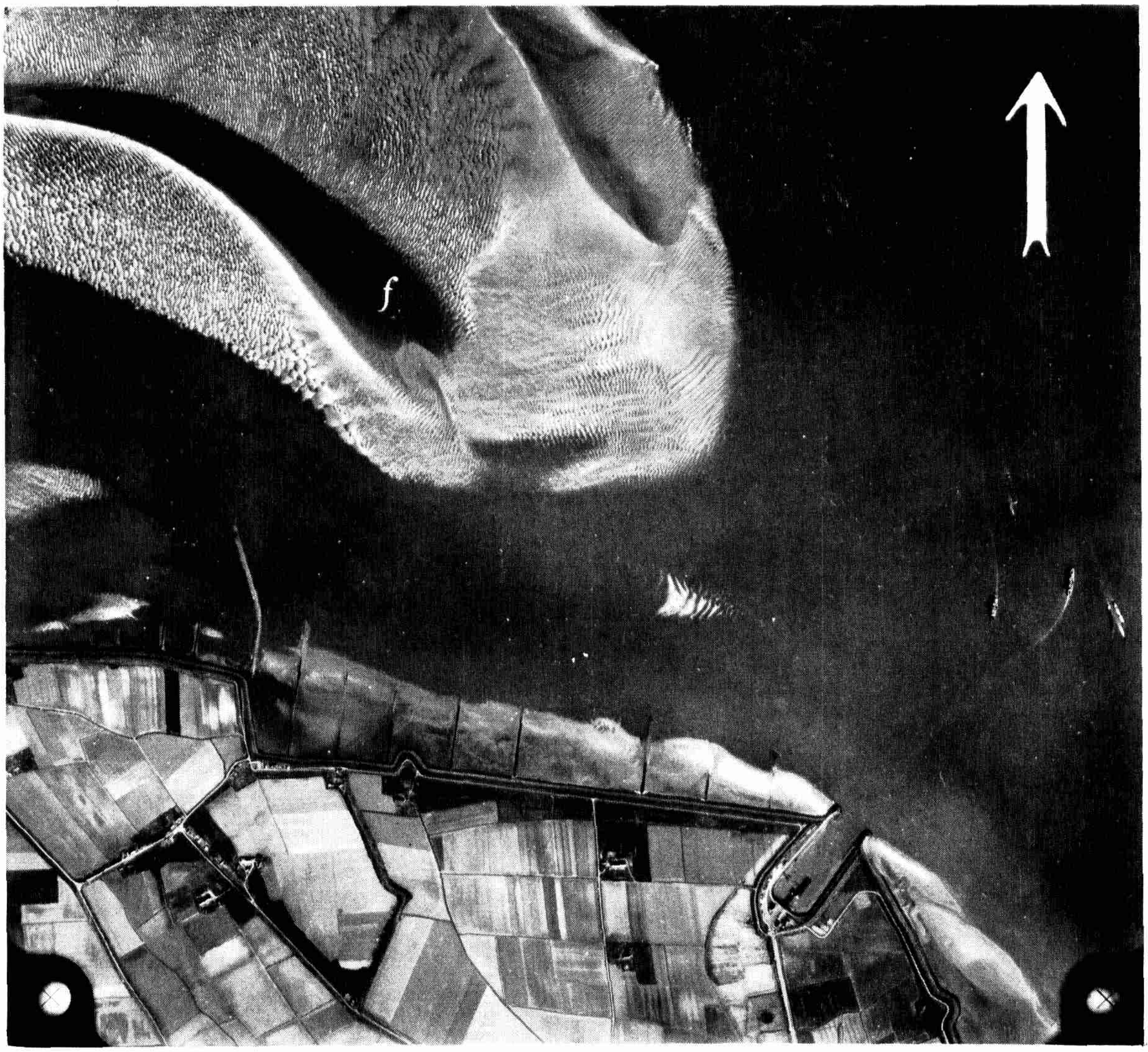

Fig. 1b

Aereal photograph showing part of Ossenisse shoal (situation 1965). Floodchannel (f), having a minor ebb 'delta' at its distal end, dissects the shoal. In the lower part the main land of Zeeuws Vlaanderen is seen with (ferry) harbour of Perkpolder (KLM Aerocarto N.V., Archief Topografische Dienst).

during flood. The trace of the erosional surface which progressively flattens upwards, gives the impression that the mega-ripple's top is blown-off.

Upbuilding of the mega-ripple during the next ebb tide starts with deposition parallel to its flood-modified surface, thereby creating the pseudo-topsets of fig. 5 (at t.)

The conclusion seems warranted that only during the more mature stages of the ebb, when current velocities have reached values which enable vortex building at the mega-ripple's lee side the latter's steepness is reestablished. Slight differences in the

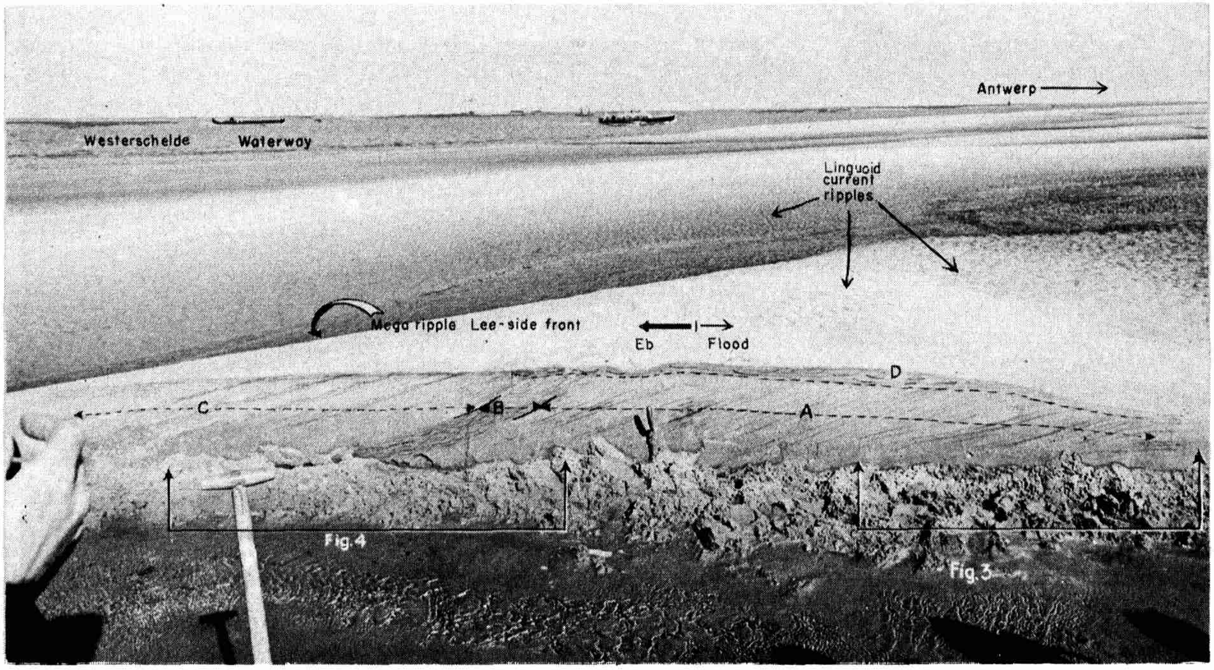

Fig. 2
View of ebb mega-ripple on Ossenisse shoal in vertical section. Observer looking NE (c.f. fig. 1b). In the backgroun. Westerschelde waterway (= ebb channel) with freight carriers. Small scale linguoid ripple marks are seen to cover the surface. Four differently structured cross-stratified intervals are shown:

A: Large scale cross-stratified set with minor unconformities between successive, variably inclined bundles of cross strata.
B: Isolated co-set of small scale cross-stratification, inclined conformably with the large scale (ebb) cross-strata.
C: Regular interbedding between bundles of large scale cross-strata and solitary, upslope-directed trains of small scale (ripple-) form sets. Upwards the latter peter out into a thin drape of slightly darker material.
D: Sub-horizontal co-set of small scale cross-stratification (= 'topset' layer) resting with erosional lower boundary upon the (ebb) mega-set. Direction of cross-stratification in intervals B and D probably is bi- or multi-directional.

angle of repose of successive bundles of cross-strata further accentuate the intermittent accretion of tidal mega-ripples.

The distinct erosional unconformities described above, betray the existence of rather strong flood currents in an ebb-dominated area.

Another type of structure is shown in fig. 4. It consists of bundles of large scale cross-strata interbedded at regular intervals with *solitary trains* of small scale cross-stratified sets climbing the 'interface'. The trains of ripple-form sets peter out upward into a ± 1 mm-thick drape of slightly darker material.

The flood currents producing these interbedded trains are interpreted to be weaker than in the former case of erosional unconformity. Instead of blowing off the top of ebb mega-ripple they make small scale ripples to ascend the latters steep lee-side face without causing much erosion.

The last mentioned structure is quite comparable with structures in the Folkstone Beds (Lower Greensand) of SW England as described by Allen and Narayan (1964), who explained, however, their generation by backflow at the lee of the mega-ripple. At the present stage of our knowledge a discrimination between the present type of alternate ebb-flood cross-stratification and the so-called interwoven, backflow-generated set frequently occurring in fluviatile sands (Boersma, 1967; Boersma, v.d. Meene, Tjalsma, 1968) is generally possible.

In the case of the interwoven set the mega-ripple and its lee side vortex-propelled small scale ripples were simultaneously active, which caused the interweaving of the respective cross-strata. With the above tidal structure, however, we have to do with separate

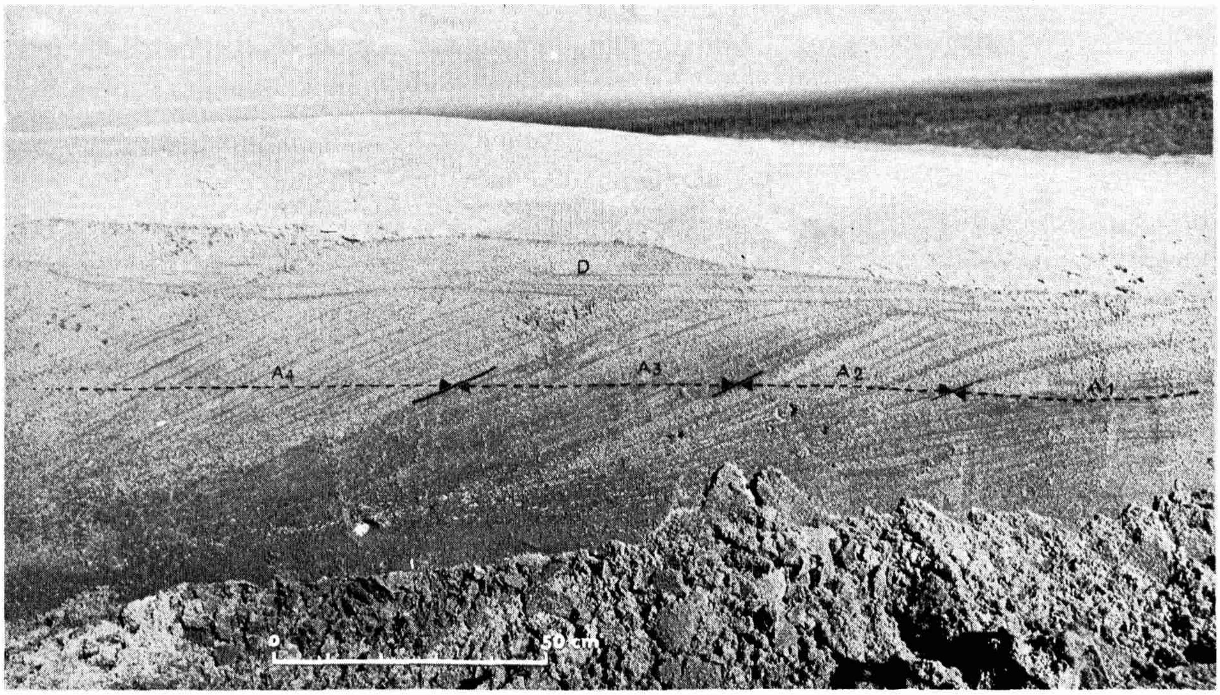

Fig. 3

Detail from fig. 2. Successive bundles A_{1-4} separated by diastems. 'Topset' layer consisting of a small scale cross-stratified co-set unconformably overlies the (ebb) mega set.

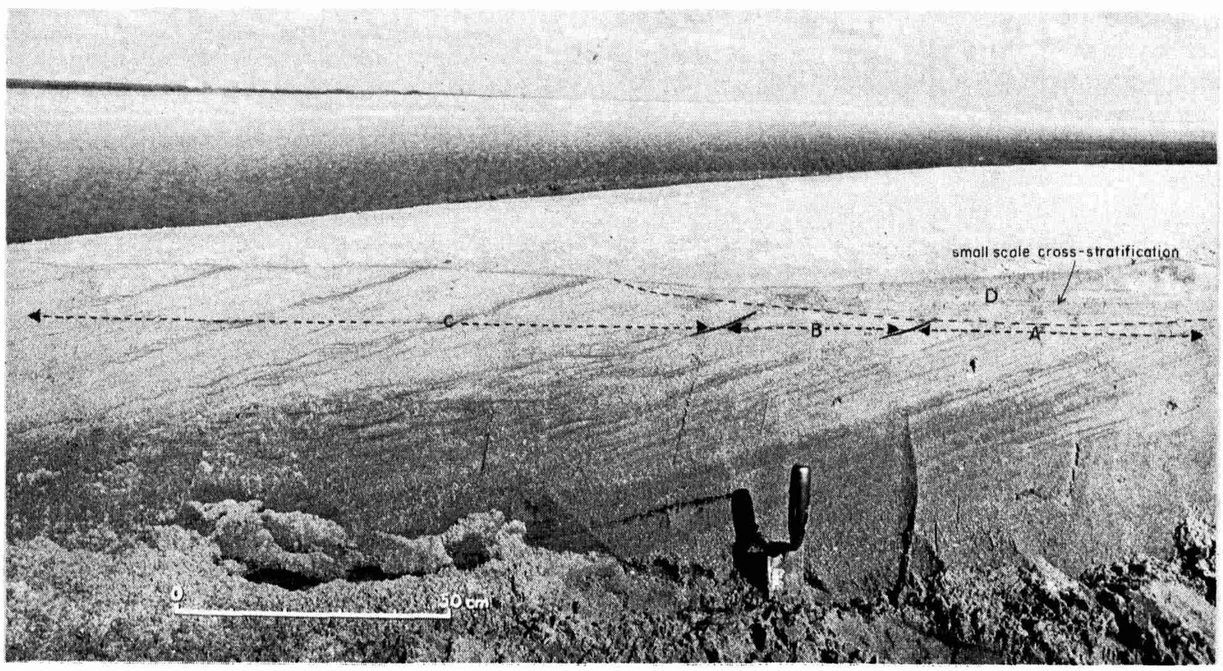

Fig. 4

Detailed picture of lefthand part of fig. 2. showing the four structural intervals described. Note the wedging out toward the left of the 'topset' coset layer. Its disappearance may be explained by the higher erosive power of the ebb stream toward the top of the mega-ripple or by selective flood erosion at the ebb ripple's front.

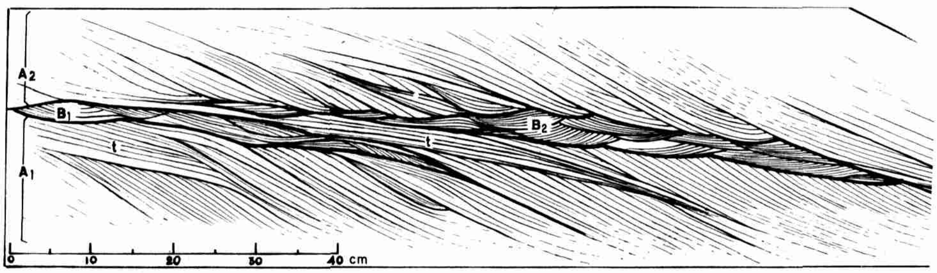

Fig. 5

Internal structure of vertically sectioned ebb mega ripple. Schematical drawing made after a lacker peel. Actual outline of mega-ripple represented by upper boundary line of the drawing. Ripple's lee side to the right. Composite internal structure showing two levels of large scale cross-stratification separated by a coset of small cale cross-strata which is comparable in character with the coset 'D' in figs. 2-4

Other comparable types of structural units are distinguished:

A bundles of mega cross-strata separated by distinct unconformable contacts (diastems)

B isolated cosets of small scale cross-strata either conformably inclined with (= B_1) or discordantly resting upon (= B_2; mark horizontal, erosional lower set boundary of the mega cross-strata.

acts: the oppositely moving (flood) ripples were active at a time when the ebb mega ripple was immobile or even subject to frontal erosion.

Still in two other ways small scale cross-stratification may play a part in the internal structure of ebb mega-ripples. In the first place in the form of a *co-set* intercalated between successive bundles of large scale cross-strata. At the present stage of investigation I will refrain from speculations regarding its generative conditions.

The other occurrence of small scale cross-stratification concerns co-sets resting discordantly and more or less horizontally upon a large scale (ebb) set. These co-sets very probably are generated by small scale ripples travelling on the stoss-side flanks of the ebb mega ripples and in their frontal troughs. (compare mega-ripple surface in fig. 2). Ebb and flood directions of cross-stratification were distinguished to occur jointly.

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