Zeitschrift: Eclogae Geologicae Helvetiae
Herausgeber: Schweizerische Geologische Gesellschaft
Band: 66 (1973)
Heft: 2

Artikel: Contourites in Niesenflysch, Switzerland
Autor: Bouma, Arnold H.
DOI: https://doi.org/10.5169/seals-164192

Eclogae geol. Helv.	Vol. 66/2	Pages 315-323	3 figures in the text and 1 table	Basle, Nov. 1973

Contourites in Niesenflysch, Switzerland

By ARNOLD H. BOUMA

Department of Oceanography, Texas A & M University, College Station, Texas 77843, USA

ABSTRACT

The *Stiegelbach section* near *Adelboden*, being part of the *Grésoschisteux formation* of the *Frutig Series* of the *Niesenflysch*, was selected for detailed study.

Most of the thin alternating beds of fine sandstone or siltstone and shale reveal distinct upper and lower bedding planes. Parallel lamination and foreset bedding are the only observed primary sedimentary structures. No vertical successions are present, characteristic for turbidites. These structures occur together with structureless zones in the sand/silt beds.

These thin beds, called *laminites* by LOMBARD, are interpreted as *contourites*, which are deposits that have been reworked by contour-following bottom currents. They form a continuum with *turbidites*, present in the same section, and which presumably form the source for reworking by bottom currents.

Introduction

The term *Flysch* has had several different connotations throughout the years, after it was introduced by STUDER in 1827 (HSÜ 1970). Yet, no single conclusive definition has been accepted. In BOUMA's (1962) glossary a description, rather than definition, is given based on publications from many investigators. Flysch can be called a sedimentary geogeneration formed just prior and during a major orogeny, and is deposited in a geosynclinal depression or foredeep. Flysch is always marine and normally even deep marine. Most Flysch sediments usually show a rhythmic appearance and normally consist of graywackes or subgraywackes alternating with shales. However, arkoses, limestones, marls, volcanic tuffs or evaporites, as well as conglomeratic elements can be the major constituents at some locations. Most Flysch sediments are poor in fossils and those present are usually reworked.

To date, no stratigraphic nor regional connotation is attached anymore to the term Flysch, except by HSÜ (1971). The total thickness of Flysch sediments, accumulated during the preparoxysmal state in submerged basins up to hundreds of kilometers in length, can have total thicknesses varying from hundreds to thousands of meters.

Several authors (WASSOJEWITH 1959; TRÜMPY 1961; MARSCHALKO 1964; TEN HAAF 1964; and others) describe Flysch and its possible subdivisions:

Flyschoid sediments and Subflysch

These sediments are not considered a Flysch formation proper, but they are closely related to them. They normally are faintly bedded marls and shales, sometimes showing an indistinct graded bedding and parallel lamination.

Wildflysch

This Flysch is deposited by gravitational sliding. It can originate at the rim of the basin or at any point within the basin. As a result, it may contain non-Flysch elements, or consists entirely of any of the other types of Flysch. Wildflysch often contains "exotic" blocks (exotic Flysch) that can be of enormous size and are difficult to recognize without detailed mapping. TEN HAAF (1957) describes large blocks (2–9 km) of regular bedded Flysch that moved off the main Italian Flysch belt and rotated during their motion. MARSCHALKO (1964) distinguishes typical and non-typical Wildflysch in the central Carpathians.

Regular bedded Flysch

This is the most well-known and most frequently occurring type of Flysch. It consists of alternating arenaceous and lutaceous layers, often interpreted as deposits of turbidity currents. Frequently it overlays *Flyschoid* sediments and occasionally underlays such formations or is enclosed on bottom and top by Flyschoid sediments. Most literature pertaining to these regular bedded Flysch deposits is summarized by KUENEN and HUMBERT (1964).

Calcareous Flysch

Since calcareous Flysch formations could not be interpreted properly for a long time, a separate group was introduced. The term has lost its uniqueness since it may belong to any of the other groups mentioned above (MEISCHNER 1964).

Although these descriptive subdivisions are ideal in discussing large formations, it does not solve any question concerning transport and deposition. Wildflysch (gravitational sliding) and turbidites represent genetic interpretations and the previously discussed subdivisions may indicate that these processes are the only ones active. The present author wants to add another depositional mechanism, namely that of contour currents (HOLLISTER and HEEZEN 1972).

Turbidites versus contourites

BAILEY (1930) described the phenomena of graded bedding within the arenaceous Flysch layers and into the overlying lutaceous sediments, while SIGNORINI (1936) presented excellent field descriptions of the Italian Flysch formations.

Experiments on transportation by density currents by KUENEN (1937, 1951) was later followed by field evidence (KUENEN and MIGLIORINI 1950; KUENEN 1952). After this a large number of investigators became interested in this concept; however, it is felt that the term *turbidite* is overused in interpretations of Flysch sedimentation. In spite of the abundance of scientific contributions and the large number of experiments, no foolproof criteria has been established for the distinction between turbidite and nonturbidite sedimentation. The present author readily agrees that turbidites can exist that do not fit his turbidite facies model (BOUMA 1962; WALKER 1967; VAN DER LINGEN 1969) (Fig. 1).

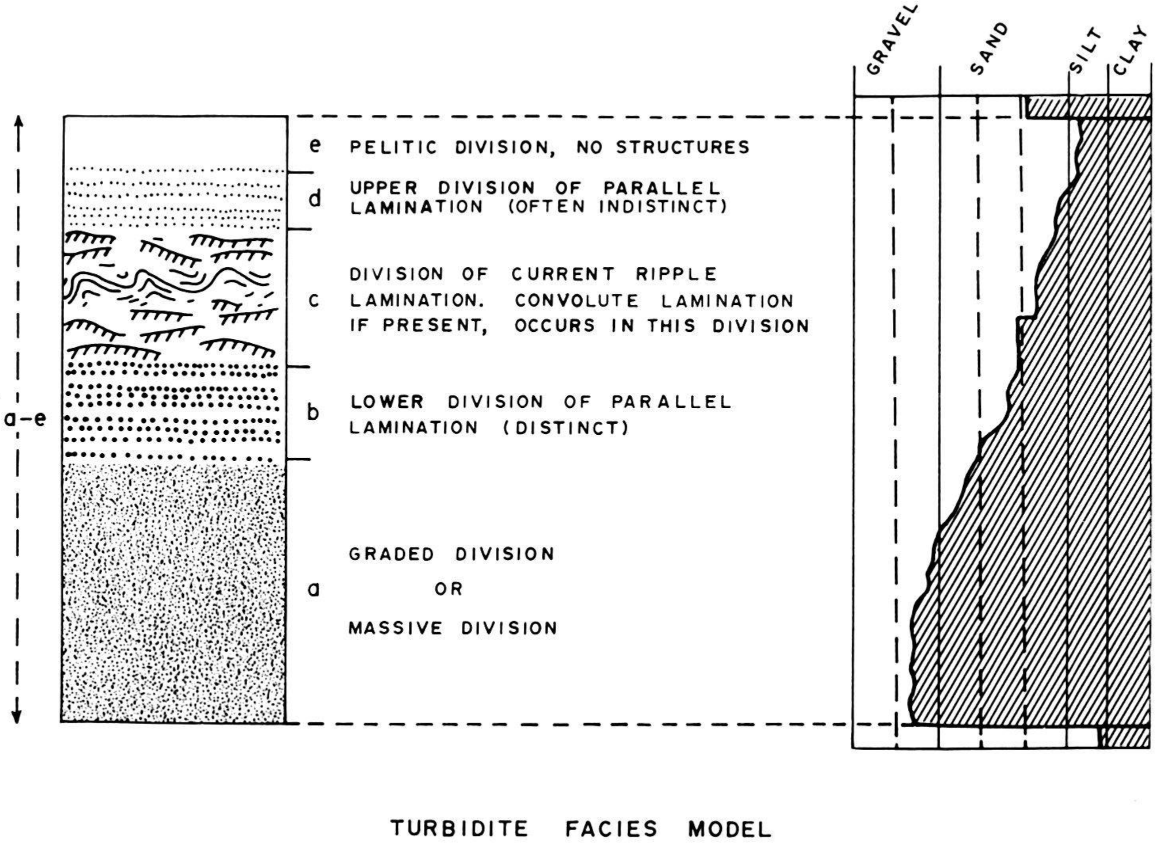

Fig. 1. Turbidite facies model as developed by BOUMA (1962). The sedimentary structure divisions and general grain size tendency are expressed.

Although the term turbidite orginated from fossil deposits, a lot of research has been done by geological oceanographers in unconsolidated sediments. Many investigators unfortunately used the term either on the basis of seismic evidence from flat floored deep basins and/or some graded bedding in sandy intercalations in long piston cores. BOUMA (1964, 1965) first reported a recent equivalent of his turbidite facies model from the submarine fan of *La Jolla Canyon*. Turbidites are defined as the deposits of turbidity currents, which are currents that carry solid particles in suspension and move as a density current over the bottom to deeper water.

Contourites involve a principle introduced by HEEZEN and HOLLISTER (1963, 1964) from oceanographic studies. The effect of bottom currents – associated with global circulation – on continental rise sediments can be observed by combining high resolution seismic profiling, piston coring and bottom photography (HEEZEN et al. 1966; HOLLISTER 1967; SCHNEIDER et al. 1967; JONES et al. 1970). HOLLISTER and HEEZEN (1967) and HEEZEN and HOLLISTER (1971) gave current evidence from bottom photographs revealing current lineations, scour marks and ripple marks from many areas.

A distinct relationship could be established between the bottom sediment characteristics and the *Western Boundary Undercurrent*, which is a deep current associated with the thermohaline circulation of the *Atlantic*. This current is a contour-following bottom current with velocities in excess of 20 cm/sec (VOLKMANN 1962), which is sufficient to form ripples in coarse silty material (REES 1966). Piston cores showed the presence of silt and very fine sand intercalations, having thicknesses ranging from 1 to 100 mm. Between 50 and 500 of these beds could be observed in the upper 10 m of most piston cores (HOLLISTER and HEEZEN 1972). The present author found similar intercalations in the bottom halves of piston cores collected from the eastern *Gulf of Mexico* in waterdepths of 1700 fathoms. Here also ripples were observed on bottom photographs and a direct or indirect interaction with the *Loop Current* is assumed. The intercalations have some characteristics that differ from turbidites as can be seen in the Table.

Table 1. Characteristic differences between turbidites and contourites (modified after HOLLISTER and HEEZEN 1972).

	Turbidites	Contourites
Bedding	Normally 5–400 cm	Normally < 5 cm
Layer contacts of sand beds	Lower contact normally sharp, upper contact normally gradual	Upper and lower contacts normally sharp
Graded bedding	Can be present as sole structure in bottom division of layer, upward decrease in grainsize normally present	Normal and reverse grading can be present; normally no graded bedding
Massive bedding	Can occur in lower division of layer	Never observed
Parallel lamination	Common structure of 2nd and 4th division of layer	Common, can be sole structure
Foreset bedding	Common structure of 3rd division of layer	Common, often together with parallel lamination
Vertical order of sedimentary structures	Fixed system recognized, BOUMA (1962)	No order observed
Fabric	Grain orientation not well developed	Grain orientation rather well developed
Matrix	10–20%	0–5%
Microfossils	Rare to common, well preserved, sorted according to size	Rare, usually worn or broken
Plant and skeletal remains	Not uncommon, rather well preserved and sorted by size	Rare and usually worn or broken
Grain sizes	Normally sand to clay, but coarser can be present	Very fine sand to silt
Inclusions other than organic	Clay and marl inclusions of pebble size can be present, especially in lower division	Never observed
Sorting	Moderate to poor	Well to very well

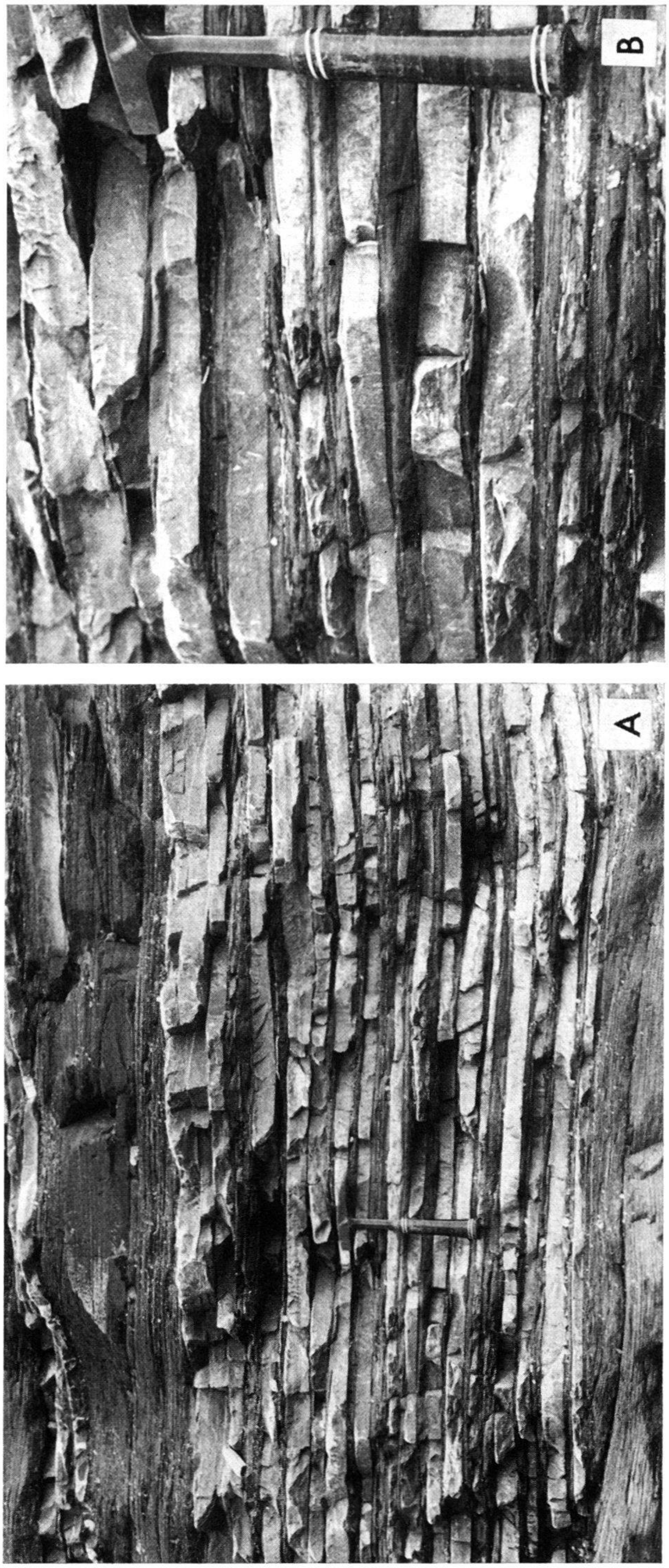

Fig. 2. *A* Overall picture of part of the Stiegelbach section in the Niesenflysch. The irregular alternation of slate and quarzitic sandstone layers, as well as the distinct upper and lower bedding planes of the sandstones are clearly visible. *B* Detail of the section near the hammer.

Niesenflysch

The *Niesenflysch* complex has been studied intensively by many investigators (see LOMBARD 1971). Primary attention has been given to the tectonics, stratigraphy and petrology. Due to its complexity little attention could be given to the sedimentological aspect. At the request of Professor A. Lombard, the present author worked on some sections (BOUMA 1962), but very little satisfactory information could be added to the already suggested interpretations.

The Niesen complex can be divided in a lower shale and sandstone division (*Frutig Series*) and an upper calcareous sandstone and conglomerate division (*Albrist Series*) (BORNHAUSER 1929). The calcareous sandstone member may partly be interpreted as proximal turbidites, while the overlaying calcareous conglomerates have characteristics of fluxo-turbidites and submarine canyon deposits.

The *Frutig Series* has been examined in the Ladholzgraben near Schmitten, Schwandfeldspitze near Horn, near Lenk and in the Stiegelbach near Adelboden (BOUMA 1962). Recently, the latter section was reexamined and sampled. The total thickness of the Niesenflysch near Adelboden is about 500–600 m (LOMBARD 1940, 1949). Fossils are very rare. The age is interpreted as Maastrichtian-Paleocene, and the environment as deep marine.

The *Stiegelbach section* represents the platy sandstone – slate members of the *Frutig Series*. The heavily tectonized area contains a rather undisturbed section just

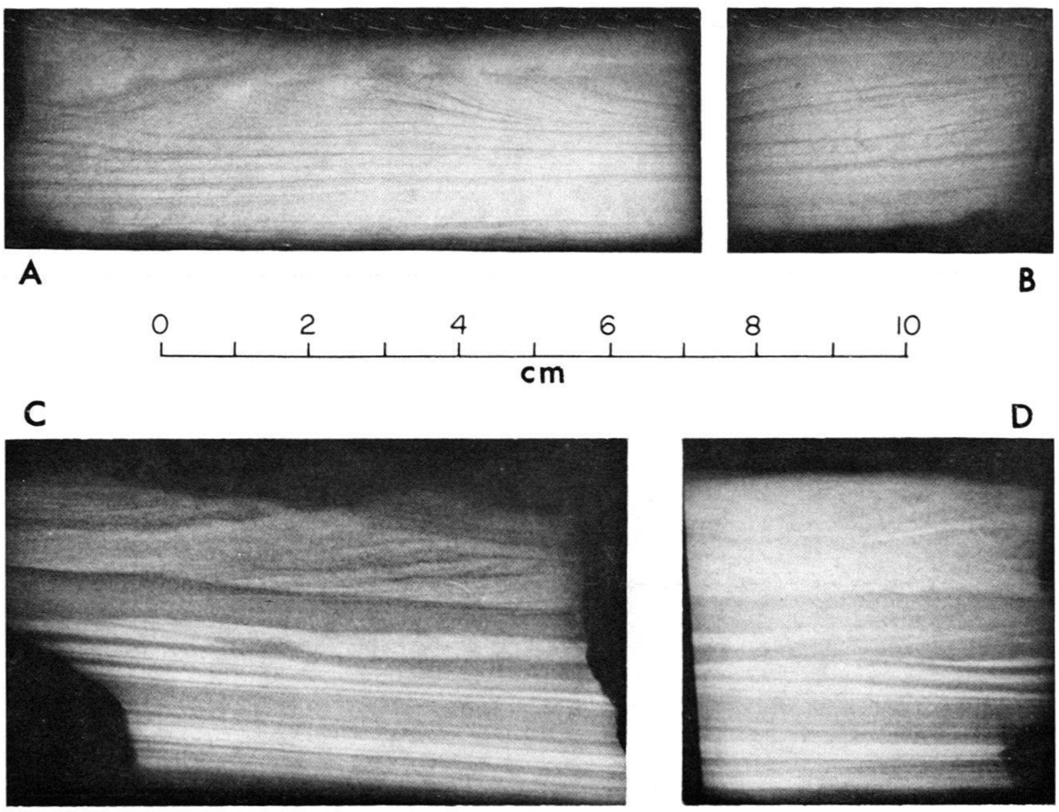

Fig. 3. *A* und *B* are radiographs from two slices cut perpendicularly from the same sample. The material is coarse silty. Parallel lamination and foreset bedding are visible. Upper portion is structureless. *C* and *D* are also from one sample, cut perpendicularly. Zones without structures, parallel lamination and foreset bedding can be observed.

below the waterfall in the Stiegelbach. The section reveals a strange rhythm, starting with shale, overlain by a sandstone layer, followed by shale and then by a series of thin sandstone layers with very little shale in between (Fig. 2*A*, *B*). This is followed again by alternations of sandstone and shale. BOUMA (1962) gives a detailed graphic representation of this part of the section (see also LOMBARD 1971).

The calcium carbonate content varies between 5 and 50 per cent, the higher values normally present in the sandstone beds as sand-sized material. The heavy mineral fraction normally comprises less than 1 per cent of the total sediment and reveals a strong weathering. The very fine sand fraction appears to be rather well sorted. It is difficult to accurately identify the original amount of clay due to recrystallization.

From this section a number of samples were cut to thin slices and then X-ray radiographed (BOUMA 1969). Some results are given in Figure 3 from which it is clear that different sedimentary structure intervals can be observed. Structureless zones may alternate with intervals containing parallel lamination and foreset bedding. No vertical succession, as known from the turbidite facies model, can be observed.

Discussions and conclusions

The NE Niesenflysch complex contains a number of different transport – deposition units. The upper calcareous division (*Albrist Series*) likely contains proximal calcareous sandy turbidites, overlain by calcareous conglomerates which, at least in part, may be called fluxo-turbidites and submarine canyon deposits. Detailed descriptions are given by LOMBARD (1971).

The lower *Frutig Series*, consisting of several members representing shale and sandy shale groups, do at least in part contain turbidity current deposits, although not always clear evidence could be obtained in the sections examined.

Outcrops in the upper part of the Stiegelbach reveal a number of sections that are not or only slightly affected by tectonism. Some of the thicker beds (> 5 or 10 cm) show indistinct graded bedding, parallel lamination and some evidence of foreset bedding. An interpretation of *turbidites* seems likely with BOUMA's b and c intervals present. Upper intervals, if occurring in the shale, can not be distinguished due to tectonic influences. The section directly below the waterfall contains some beds that may be turbidites, while most of the thinner ones fit the concept of *laminites*. LOMBARD (1963, 1971) introduced this latter term for the type of deposits that reveal only parallel lamination and parallel thin bedding. This descriptive term has all the advantages of not being processes orientated and as such should be maintained. The thin beds of the Stiegelbach section, however, confirm with most characteristics indicated in the Table 1, occur together with turbidites, and therefore may be interpreted as *contourites*. A more definite answer may be given if the paleogeographic history of the complex Niesenflysch can be unraffled in detail (see LOMBARD 1971). On the other hand, however, an interpretation of contourites will be helpful in paleogeographic studies indicating global-type circulation with continental rises allowing contour-following bottom currents to operate (TUCHOLKE et al. 1972).

The bottom currents rework the present sediments and its winnowing action results in a concentration of grainy material. Oceanographic observations indicate that velocities can be measured in abyssal depths that enable transport of silt and fine sand which explains parallel and oblique laminations. The most likely transport agent to bring this type sediment to these depths are turbidity currents, and most contourites therefore may well originate from turbidites (HOLLISTER and HEEZEN 1972). The few millimeter-thin silt bands likely are lag deposits of winnowing action of muddy material, which can be upper parts of turbidites or fine detrital-pelagic deposition with scattered silt or fine sand grains resulting from aolian transport. Normal pelagic deposits, once winnowed out, most likely leave lag deposits primarily consisting of skeletal material.

Observations in the eastern Gulf of Mexico clearly indicate that bottom currents are far from being continuous since ripple marks are partly covered with plant fragments and fine mud (PEQUEGNAT et al. 1972). The sharp upper and lower bedding planes, zones with parallel and/or oblique lamination mixed with structureless zones, and the sorting of the material is not characteristic for turbidites. With the present knowledge in mind, the interpretation *contourite* may be the most logical one.

Acknowledgments

Fieldwork was carried out in September 1971, after the VIII International Sedimentological Congress in Heidelberg. Funds were provided by the Office of Naval Research under contract N00014-68A-0308-0002.

The writer wishes to express his appreciation to Dr. Charles D. Hollister for his constructive remarks about the manuscript, to Mrs. Karen Weaver for the laboratory work and to Mrs. Susan McMurrey for the typing.

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