Annales Societatis Geologorum Poloniae (1989), vol. 59:351-390
PL ISSN 0208-9068

CHARACTERISTICS AND ORIGIN OF FLUXOTURBIDITES FROM THE CARPATHIAN FLYSCH (CRETACEOUS – PALAEOGENE), SOUTH POLAND

Stanisław Leszczyński

Instytut Nauk Geologicznych, Uniwersytet Jagielloński, ul. Oleandry 2a, 30-063 Kraków, Poland

Leszczyński S., 1989. Characteristics and origin of fluxoturbidites from the Carpathian flysch (Cretaceous – Palaeogene), south Poland. *Ann. Soc. Geol. Polon.*, 59:351-390

Abstract: Selected beds (164) of coarse-clastic resedimented deposits, traditionally called fluxoturbidites, were described in detail from various flysch formations (Cretaceous – Palaeogene) of the Polish Carpathians, with particular emphasis given to texture, sedimentary structure and bedding characteristics. The beds were classified into three textural groups. For each of these groups model beds were generated, using vertical-transition count technique. The ideal bed for conglomeratic fluxoturbidites (group CS) and that for pebbly sandstone fluxoturbidites (group PS) correspond basically to Lowe's (1982) model beds of the deposits of high-density gravelly and sandy turbidity currents, respectively. The ideal bed of sandstone fluxoturbidites (group S) corresponds to the classical turbidite showing expanded Bouma T_a division overlain by reduced sequence T_{b-e}. The classical fluxoturbidites are thus interpreted as the deposits of high-density turbidity currents, although other mechanisms, including cohesionless debris flows and fluidized flow, may have also contributed locally. Composite beds which dominate in the fluxoturbidites represent an effect either of amalgamation of several separate flow events or deposition from surging flows.

Key words: sediment-gravity flows, turbidites, fluxoturbidites, flysch, Carpathians.

Manuscript received 25 September 1987, revision accepted 5 November 1988

INTRODUCTION

During the current decade our knowledge on sediment gravity-flow processes and their products has increased considerably. Particularly, a significant progress has been made in understanding of coarse-grained resedimented deposits (for a review, see Lowe, 1982; Nemec & Steel, 1984; Pickering *et al.*, 1986). This facies category includes, among others, thic-bedded conglomeratic and sandstone deposits, called fluxoturbidites. Such deposits, together with classical turbidites, occur within a number of flysch succession.

The term fluxoturbidites was coined by Dżułyński, Książkiewicz and Kuenen (1959) to describe flysch deposits that are characterized by thick, irregular, commonly composite bedding, sandy to conglomeratic textures, poorly developed normal grading and essentially massive appearance, although flat lamination, large-scale cross-bedding and shaly cappings may also be present locally. Dżułyński and others (1959) interpreted the fluxoturbidites as mass-gravity deposits intermediate between those laid down from gliding, slumping and turbidity currents. Fluxoturbidite beds were first described in detail by Unrug (1963) from the Cretaceous Istebna Beds, in the Polish Carpathians – a *locus typicus* of fluxoturbidites.

The term fluxoturbidite did not gained much popularity, and some geologists suggested even that it should be abandoned, as defined imprecisely (Walker, 1967). Others, however, saw it as an useful descriptive denominator (e.g. Stanley & Unrug, 1972; Schlager & Schlager, 1973), encompassing deposits belonging to different genetic and descriptive groups (e.g. Facies A and B of Mutti & Ricci Lucchi, 1972, 1975; Walker & Mutti, 1973; grain-flow, fluidized-flow and debris-flow deposits according to clasification by Middleton & Hampton, 1973, 1976). Carter (1975) coined the term fluxoturbidity flow to describe a transportation process which is responsible for deposition of fluxoturbidite beds.

Geologists working in the Carpathians long recognized the distinctive character of fluxoturbidites among other flysch deposits, but failed to propose a satisfactory explanation for the origin of fluxoturbidite beds. Ślączka and Thompson (1981) re-investigated the Carpathian fluxoturbidites and proposed fluxoturbidite bed model. However, this model appears to be little representative for the spectrum of fluxoturbidite variability. Moreover, the genetic interpretation of the fluxoturbidites, advocated by Ślączka and Thompson (1981), is difficult to accept in light of modern knowledge of sediment-gravity flow processes.

The fluxoturbidite beds appear now to be best explained in terms of the theory of high-density turbidity currents developed by Lowe (1982), although the variability of these beds does not fall fully into Lowe's high-density turbidite bed models. This paper focuses on the relationships between fluxoturbidites and the deposits of high-density turbidity currents and attempts to establish position of fluxoturbidite facies within recent classifications of sediment gravity-flow deposits and in deep-sea clastic models.

MATERIAL AND METHODS

Field material which provide the descriptive basis for the ensuing discussion includes logs of 164 fluxoturbidites beds selected from different stratigraphic units of the Carpathian flysch (Cretaceous – Palaeogene) (see Fig. 1 and Table 1 for location of measured sections). Descriptive features noted in the field have included bed thickness, character of bedding (simple, composite), types of sedimentary structures and their position within a bed. Conglomeratic, sandstone and shaly lithologies, when present within a single bed, were considered as separate structural divisions. Preferred vertical sequences of

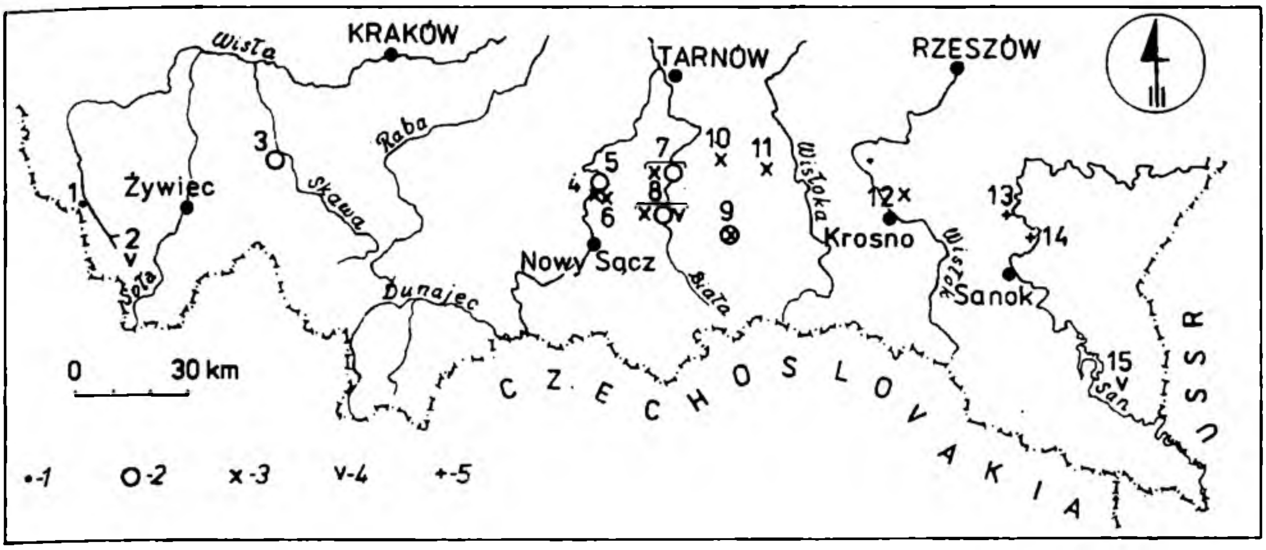


Fig. 1. Map showing lithostratigraphic and areal distribution of sections studied. *1* — Godula Beds; *2* — Istebna Beds; *3* — Ciężkowice Sandstone; *4* — Krosno Beds; *5* — Kliwa Sandstone. Location of sections: 1 — Ustroń Poniwiec; 2 — Koniaków Koczy Zamek; 3 — Mucharz; 4 — Znamirowice and Tabaszowa; 5 — Rożnów; 6 — Gródek n.Dunajcem; 7 — vicinity of Ciężkowice (Jastrzębia, Kąśna, Kipszna, Bogoniowice, Ostrusza); 8 — vicinity of Bobowa (Stróżna, Szalowa, Wilczyska, Chodorowa); 9 — Gorlice; 10 — Rzepiennik, Jodłówka Tuchowska; 11 — Szerzyny, Czermna; 12 — Lęki Strzyżowskie, Czarnorzeki; 13 — Kamienna, Witryłów; 14 — Łodzina; 15 — Polana

different structural-textural divisions were analyzed using transition probability matrices. The sequential analysis led to the recognition of three groups of fluxoturbidite beds, differing in granulometry and sedimentary structure assemblages. Each of these groups was characterized by an ideal (model) bed and a most frequent (modal) bed.

DESCRIPTION OF FLUXOTURBIDITES

TEXTURE AND COMPOSITION

Fluxoturbidites are mainly coarse sandstones containing variable admixtures of small pebble-sized clasts. The latter occur either dispersed within sandstone beds or are concentrated near the base of a bed. Less common are pure conglomeratic and fine-sandstone beds. Coarse-grained beds dominate among the fluxoturbidites from the Istebna Beds (Unrug, 1963; Ślączka & Thompson, 1981) and the Ciężkowice Sandstone (Pl. II: 1; Leszczyński, 1981), while fine-grained ones occur predominantly in the Krosno Beds (Ślączka & Thompson, 1981) and the Kliwa Sandstone. Petrographically, most of the studied sandstones are quartzose to quartz-feldspathic arenites, poor wackes (Istebna Beds — Unrug, 1963; Ciężkowice Sandstone — Leszczyński, 1981), and rarely wackes (Krosno Beds — Shideler *et al.*, 1975). Common constituents of the fluxoturbidites beds are shale intraclasts which may attain

Table 1

Summary of exposures studied

Lithostratigraphic unit	Age	Tectonic unit	Locality	Locality number in Fig. 1
Krosno Beds	Oligocene	Fore-Magura, Silesian	Koniaków – Koczy Zamek[a]	2
			Stróżna[b]	8
			Polana[a]	15
Kliwa Sandstone	Oligocene	Skole	Łodzina (San River valley)	14
			Kamienna – Witryłów (road cuts)	13
Ciężkowice Sandstone	Upper Paleocene – Lower Eocene	Silesian	Znamirowice, Tabaszowa[b]	4
			Gródek n.Dunajcem (on the lake-shore)	6
			Ciężkowice, Bogoniowice, Kąśna, Jastrzębia[b]	7
			Stróżna[b]	8
			Gorlice (Sękówka Stream)	9
			Rzepiennik, Jodłówka Tuchowska[b]	10
			Szerzyny, Czermna[b]	11
			Łęki Strzyżowskie[a], Czarnorzeki[b] (vicinity of Odrzykoń Castle, „Prządki" Tors)	12
Istebna Beds	Senonian – Paleocene	Silesian	Mucharz (Skawa River valley)	3
			Rożnów[a]	5
			Kipszna, Kąśna, Siekierczyna[b]	7
			Jankowa, Bobowa-Koczanka	8
			Gorlice (Sękówka Stream valley)	9
Godula Beds	Lower Senonian	Silesian	Ustroń-Poniwiec[a]	1

[a] quarry; [b] many different exposures.

a few tens of cm in size. The topmost parts of the beds are often enriched in coalified plant detritus which locally forms laminae composed of bright coal. This detritus is coarser than the enclosing siliciclastic material.

Pebbles and intraclasts show either random fabrics or are non-imbricated with *A*-axes preferentially aligned parallel to flow. *A*-axis parallel and *A*-axis imbricated fabrics were also noted in some beds (Pl. IV: 1; Fig. 2).

BEDDING

Fluxoturbidites are irregularly and commonly indistinctly bedded. Bedding is accentuated by shale interbeds (Pl. I: 2) which usually show gradational lower contacts and are laterally impersistent even in small exposures. Some 72% of the measured beds show a gradational transition into overlying shales. Signs of internal amalgamation are very common (Pls. I and II).

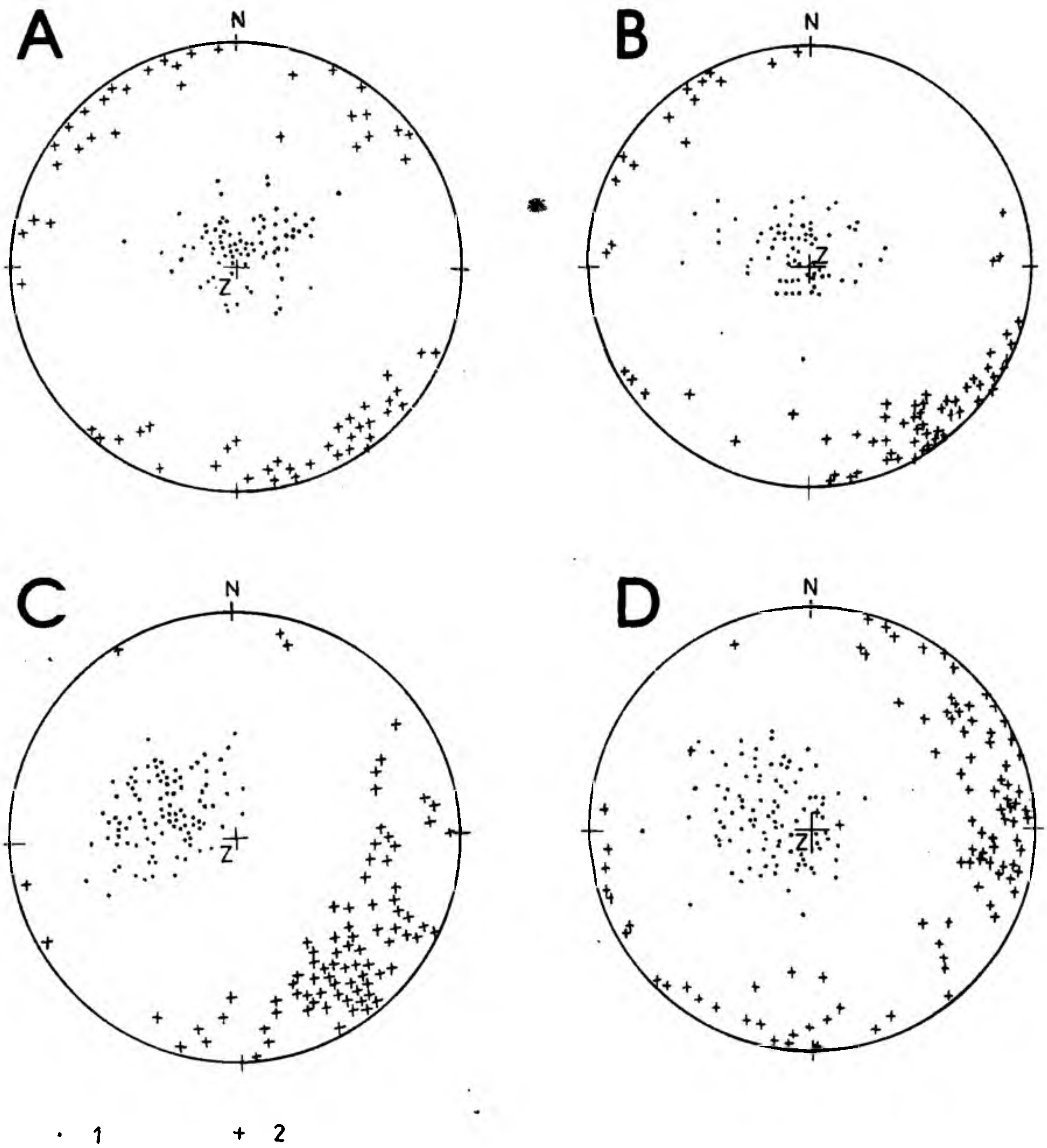


Fig. 2. Lower hemisphere projections of normals to clast AB-planes (*1*) and clast *A*-axes (*2*) in fluxoturbidite beds from the Ciężkowice Sandstone. Localities: *A*, *B* — Biecz; *C* — Czarnorzeki, *D* — Jastrzębia near Ciężkowice

The term *bed* is here applied to distinct layers bounded at the base and top by shale. Beds lacking any internal discontinuities and showing single structural cycle (vertical sequence of sedimentary structures within one fining upward unit) are here referred to as *simple beds* (Fig. 3). Beds displaying internal discontinuities and several structural cycles are *composite beds* (Wood & Smith, 1958) (Fig. 3; Pls. I: 1 and II: 1). Layers within the composite beds, composed of single structural cycles and bounded by more or less recognizable discontinuity planes, are referred to as *elementary beds* (Fig. 3; Pls. I: 2 and II: 1). The tompost layer of a composite bed, followed upward by shale is termed as *pseudosimple bed.* The latter differs from simple bed in having a diffuse base.

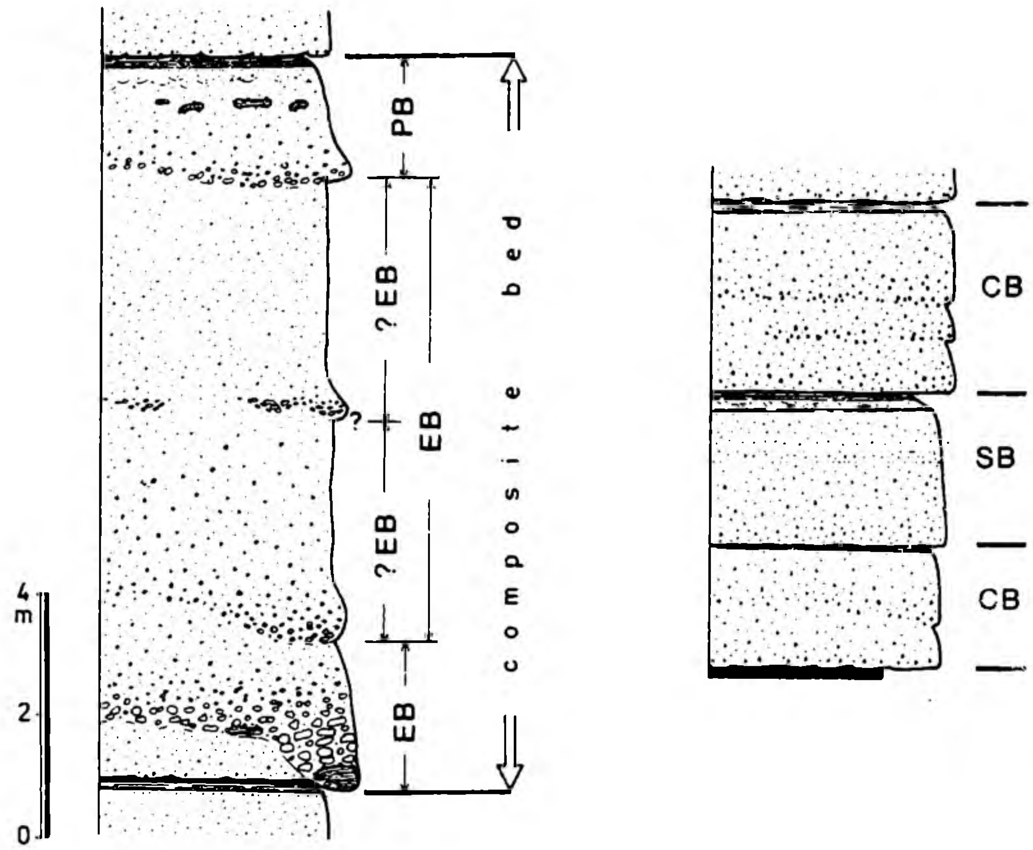


Fig. 3. Terminology of bedding adopted for description of fluxoturbidite deposits. *CB* — composite bed; *SB* — simple bed; *EB* — elementary bed; *PB* — pseudosimple elementary bed

Among 164 measured beds 45 were classified as simple beds and the rest as elementary beds. Within the latter 38 pseudosimple beds and 81 elementary normal beds were recorded.

The thickness of the simple beds varies from 1 to several m, max. up to 10 m (Figs. 4 and 6). The mean thickness of 63 simple and pseudosimple beds measured is 2.7 m (Fig. 4). The composite beds range in thickness from more than 1 m to a few tens of m (Unrug, 1963; Ślączka & Thompson, 1981; Koszarski & Koszarski, 1985). The bedding planes of the simple and composite beds vary from flat, to highly loaded and/or scoured with the relief up to a few tens of cm. Flat soles bear a variety of tool marks. Amalgamation surfaces are commonly uneven (Pls. I, II and IV: 2).

INTERNAL STRUCTURES

The following structures were identified in the fluxoturbidite beds: (1) homogeneous (ungraded, non-laminated), (2) normal grading, (3) inverse grading, (4) horizontal fine-sand lamination, (5) large-scale cross-stratification, (6) water-escape structures, and (7) structures of the Bouma T_{b-e} sequences. Structurally uniform parts of a bed were referred to as structural divisions. Structures 1 – 6 occur in the main sandstone or conglomerate/sandstone layer of the beds, while Bouma divisions are limited to the topmost levels of the

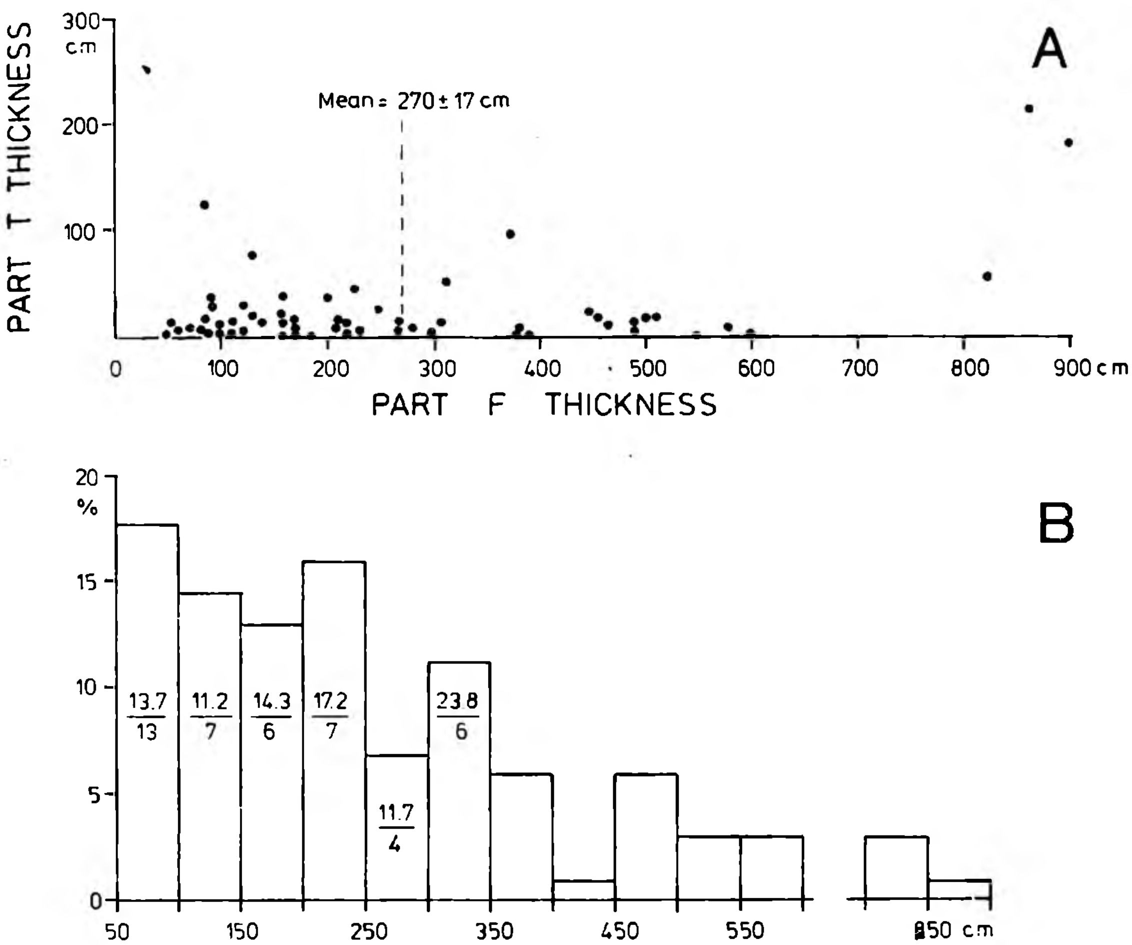


Fig. 4. Thickness characteristics of simple and pseudosimple fluxoturbidite beds (63 beds). (*A*) Plot of thickness of part F against thickness of overlying part T. (*B*) Thickness distribution of unit F; numbers given in histogram columns are mean thickness (cm) of part T (lower number) and mean percentage of part T within entire bed (upper number)

simple and pseudosimple beds. Following Ślączka and Thompson (1981), the fluxoturbidite beds were divided into two parts. Part F includes a sandstone or conglomeratic sandstone displaying structures 1 to 6 and part T shows structures of the Bouma turbidite. The latter unit is a few to a dozen or so cm thick (Pl. I: 1; Fig. 6) and occupies less than 10% of the thickness of a simple or pseudosimple bed. Part T does not occur in the elementary normal beds.

Homogeneous division. This division is typified by the absence of macroscopically discernible signs of grain-size gradation and lamination, and is the most characteristic one for the fluxoturbidite beds (Tables 2 & 3; Figs. 5 & 6). At first sight it appears to comprise a 60–90% of a bed thickness (Pl. I: 2), but under a closer inspection it is not more than 50% of a bed. The homogeneous structure is commonly characteristic for the middle and upper part of the simple and elementary beds. Frequent are beds showing two homogeneous levels. The lower level is usually coarser than the upper and they are commonly separated by either a normally graded division or a plane laminated one (Table 3; Figs. 8, 12 and 13).

Table 2

Summary of sedimentary structures in fluxoturbidite beds

Structure	Frequency	
	number of beds	per cent of beds
1 Cross stratification	8	4.9
2. Basal inverse grading	7	4.3
3. Homogeneous conglomerate	13	7.9
4. Normal grading in conglomerate	67	40.8
5. Horizontal fine-sand lamination in pebbly sandstone	47	28.6
6. Water-escape structures	9	5.5
7. Homogeneous sandstone	102	62.2
8. Normal grading in conglomerate	83	50.6
9. Plane parallel lamination in fine to medium sandstone (T_b)	61	100.0
10. Cross, wavy and convolute lamination in coarse silt to very fine sandstone (T_c)	19	31.1
11. Parallel lamination in muddy shale (T_d)	53	86.9
12. Homogeneous clay (T_e)	5	8.2

Structures 1—8 were identified in 164 beds (54 simple, 38 pseudosimple and 81 elementary normal beds). Structures 9—12 were identified in 61 beds in which part F passes upwards into part T.

Table 3

Types and number of structural sequences within part F of 164 beds. Structural divisions marked with numbers as in Tab. 2.
E —elementary normal bed; S — simple or pseudosimple bed

Type of sequence	Number of beds E	S	Type of sequence	Number of beds E	S	Type of sequence	Number of beds E	S
1-5-7	1		4-5-4-8		1	7	16	
1-5-7-5-7	1		4-5-8-7	3	1	7-5-7	8	8
1-7-8	5		4-5-7	3	2			
1-8-5-7		1	4-5-7-5-7	1		8	4	22
			4-5	3		8-5-7-8		3
2-5-3	1		4-7-8		2	8-5-7	3	2
2-3-4	2		4-7-6	2		8-5-6		2
2-3-4-8	2	2	4-7	12	9	8-7	3	9
			4-8-7-8		3	8-6		3
3	2		4-8	1	10	8-5	2	
3-4	1		4-6	2				
3-4-7-8		3	4	2				
		3	5-7-8	1				

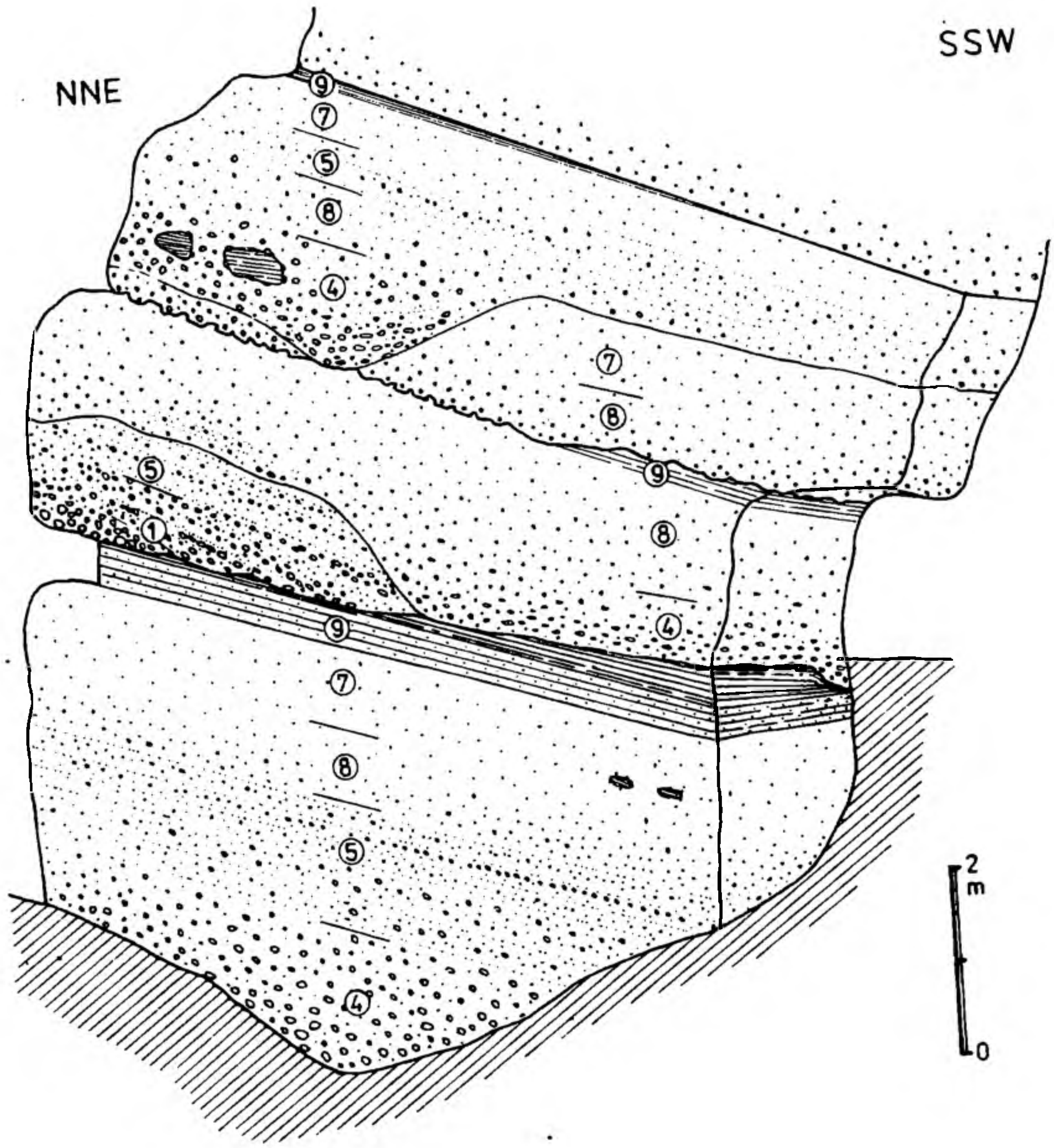


Fig. 5. Bedding and structures of conglomeratic and pebbly sandstone fluxoturbidite beds (groups CS and PS) at the Warownia Tor in the Skamieniałe Miasto protected site near Ciężkowice; Locality No. 7 in Fig. 1; comp. Pls. I:2 and III:1. Numbers refer to structural divisions explained in Table 2. Simple bed is followed upwards by composite beds showing conspicous channelling and rapid lateral changes in texture and structural development; note low-angle inclined parallel laminae in middle bed. These composite beds were probably deposited from surging flows

Normal grading (Pls. II: 1 and IV: 1; Figs. 5 and 7). This is the second most frequent structure in the fluxoturbidite beds analyzed (Tables 2 and 3). It becomes better marked with increasing pebble-fraction contents. Coarse-tail grading predominates. Beds with scarce pebbles look superficially ungraded, but a closer inspection reveals a widespread occurrence of normal grading. It is best manifested near base and top of a bed. Graded interval occurs often twice in a conglomerate/sandstone bed, being separated by homogeneous sandstone or pebbly sandstone. Homogeneous and normally graded portions display either chaotic clast orientations, or there is a flow parallel *A*-axis clast alignement or, rarely, an up-flow *A*-axis imbrication (Pl. IV: 1; Fig. 2).

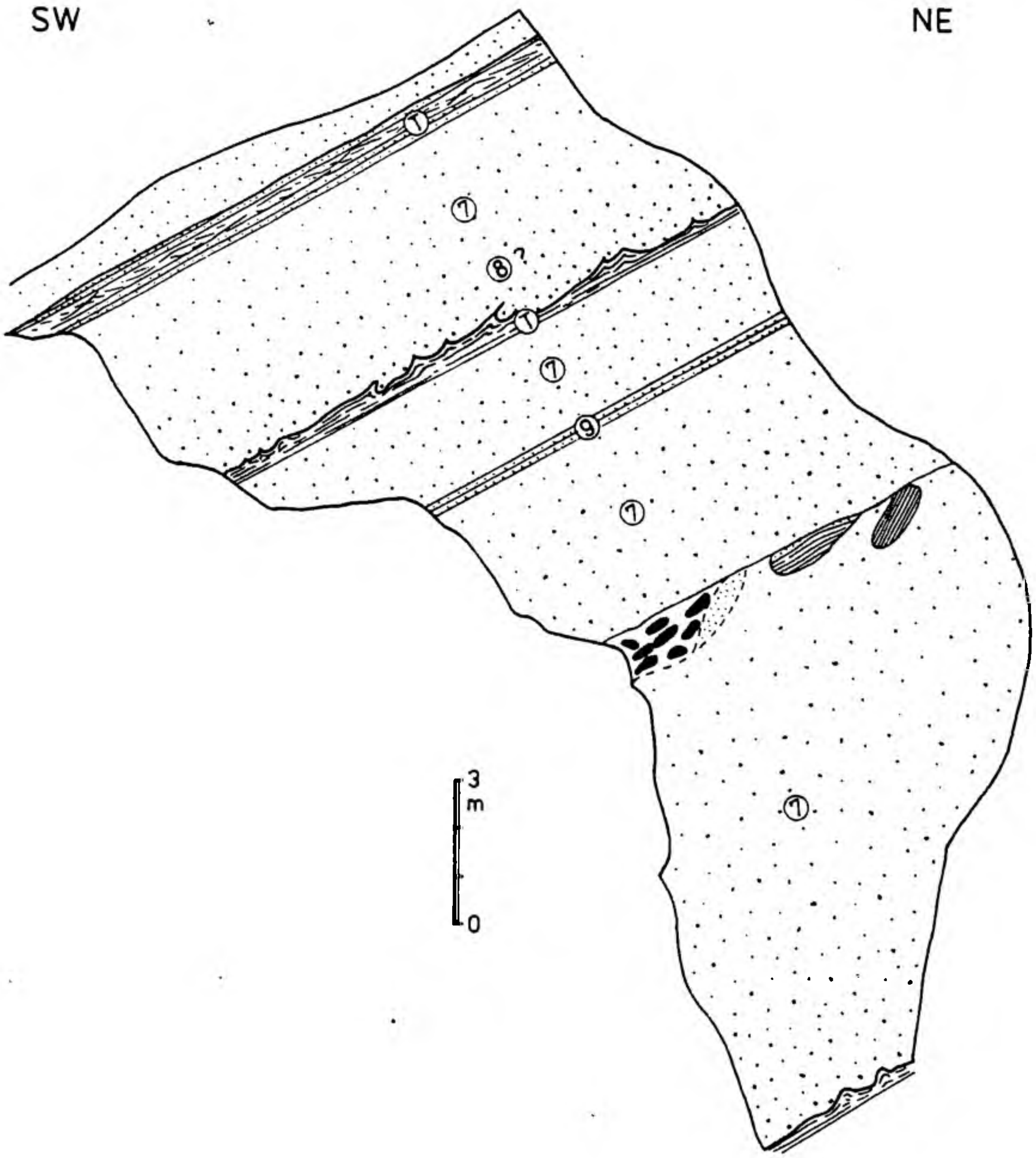


Fig. 6. Field examples of sandstone fluxoturbidite beds (group S) at quarry Polana; Locality No. 15 in Fig. 1 (modified after Ślączka & Thompson, 1981), showing simple and composite beds. Numbers refer to structural divisions explained in Table 2; *T* — Bouma T_{b-e} sequences. Note large thickness of beds, their homogeneous nature, intraclast-rich levels and load casted bases

Inverse grading. This grading type is well-developed in the basal level of beds commencing with conglomerate (9 beds, Tables 2 and 3). The beds have sharp, flat, often loaded soles which are followed upwards by inversely graded pebble zone, up to several cm thick (Pl. IV: 1). This zone rapidly dies out upwards within an ungraded conglomerate. Inverse grading is also present within granule conglomerate or sandstone displaying fine-sand lamination (Fig. 5; Pl. III: 1).

Horizontal fine-sand lamination (Pls. I: 2, II: 2, III: 1 and IV: 2; see shear lamination in Carter, 1975; Postma *et al.*, 1983; Leszczyński, 1985). This lamination was found in 47 beds (Table 2) composed of conglomeratic

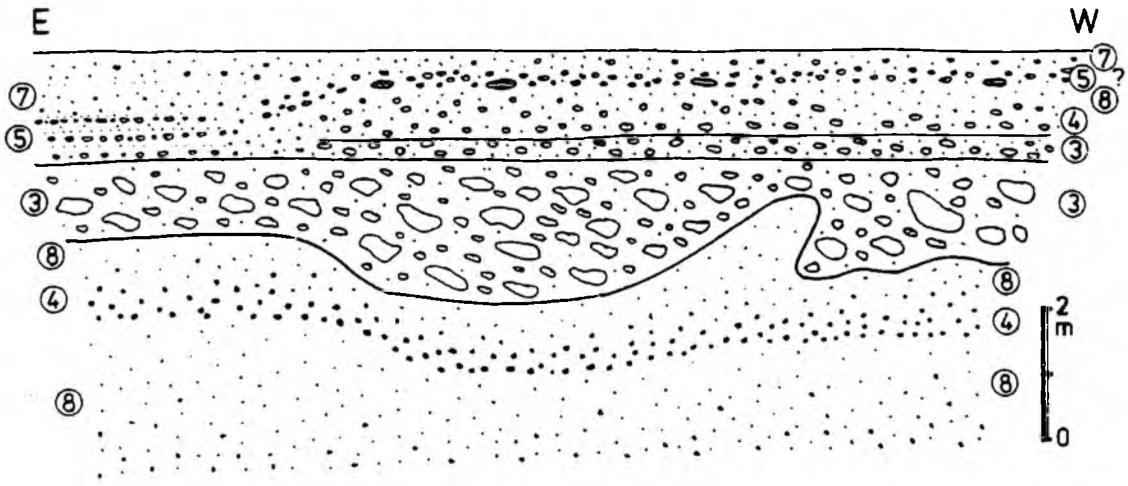


Fig. 7. Field sketch of conglomeratic and sandstone fluxoturbidite beds (group CS and PS) at Mucharz; Locality No. 3 in Fig. 1 (modified after Ślączka & Thompson, 1981). Numbers refer to structural divisions explained in Table 2. Note thick conglomerate bed showing load-enhanced scours along base. Elongated clasts show longitudinal *A*-axis alignement and weak upflow imbrication

sandstone and pebbly sandstone. It is delineated by fine sandy laminae present within a coarser sediment. Both lower and upper contacts of these laminae may be gradational, although downward transitions are commonly sharper and more abrupt (Pl. III: 1). Upward transitions are accompanied with inverse grading developed in a zone, 3 – 8 cm thick, which is often capped by a granule lamina. Fine-grained laminae are 1 – 2 cm thick and are spaced at several cm to a few tens of cm apart. The lamination is best seen on weathered surfaces, forming positive rib-like forms (see Nemec & Steel, 1984, Fig. 17). These flat laminae occur most frequently in higher levels of part F in zones depleted in pebble-sized grains (Table 3; Pl. II : 2), occasionally extending downwards to the base of the unit (Pl. II: 2). In four elementary normal beds such laminae were noted to extend upwards to the topmost level (Pl. IV: 2). The laminae occur either as single ones or in sets. Very thick beds commonly reveal a number of such laminae-sets which are separated by ungraded, structureless portions, up to a few tens of cm thick. (Table 3).

Large-scale cross-stratification. This structure was noted near bases of eight pebbly sandstone and conglomeratic sandstone beds (Tables 2 & 3). Five beds display typical trough cross sets, up to 30 cm high (Pl. III:2; Fig. 8). The cross-sets are picked out by pebble concentrates and fine-sand laminae, with pebbles clustered within toesets.

Three beds show a peculiar form of cross-stratification in which tangential cross-laminae deliceated by fine sand, vanish upwards and downwards in and are laterally enclosed by homogeneous sandstone (Figs. 5, 9 and 10). Coset of such tangential cross-stratification, dipping at an angle of 45°, was encountered in one bed (Fig. 10).

Water-escape structures. In nine beds dewatering structures were found (Tables 2 and 3). They are all dish structures which occur in the middle and

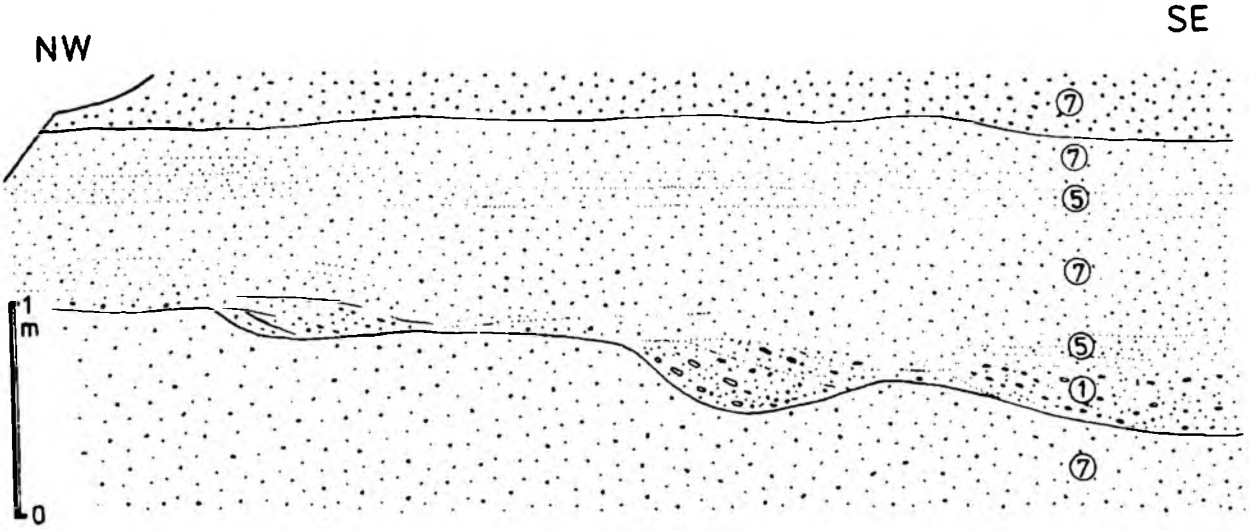


Fig. 8. Field sketch of composite pebbly sandstone bed (group PS) at the Skamieniałe Miasto protected site, near, Ciężkowice; Locality No. 7 in Fig. 1. Numbers refer to structural divisions explained in Table 2. The middle bed shows isolated trough cross-sets followed up by essentially homogeneous sandstone bearing two crude intervals with plane fine-sand laminae

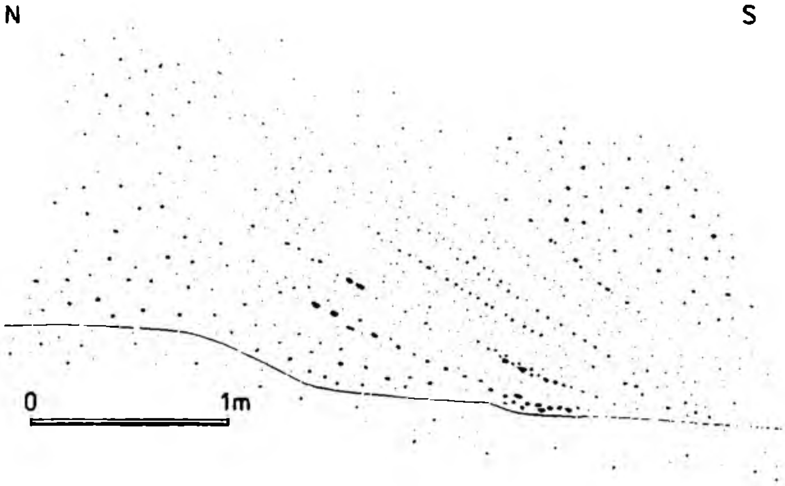


Fig. 9. Field example of cross-stratification near base of elementary pebbly sandstone bed (group PS) exposed west of Odrzykoń Castle; Locality No. 12 in Fig. 1. Cross-strata are delineated by parallel fine-sand laminae alternating with thicker, conglomeratic laminae locally showing well-developed inverse grading. Cross-stratification dies out upwards and northwards within homogeneous sediment and is developed in front of pebbly sandstone lens that wedges out southwards

upper levels of homogeneous and normally graded intervals and are generally limited to the upper parts of the beds. The dish structures die out gradually upwards, either within these intervals or are followed by a flat laminated sandstone (T_b). Some ungraded and graded divisions reveal short (up to 10 cm), uneven fractures aligned parallel to the bedding and having slightly upturned edges. These structures may also be of dewatering origin.

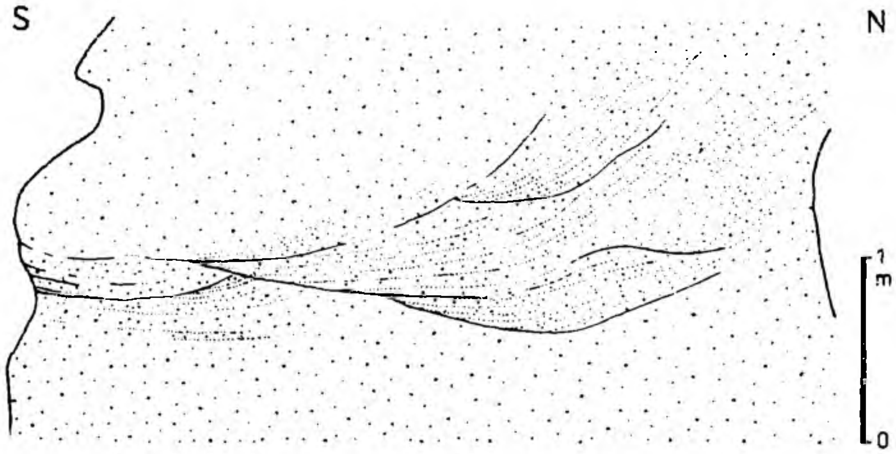


Fig. 10. Fragment of composite pebbly sandstone bed (group PS) exposed at Niedźwiedź Tor in the Skamieniałe Miasto protected site near Ciężkowice; Locality No. 7 in Fig. 1. Upper elementary bed shows trough cross-stratification picked out by fine-sand laminae and coarse-sand ones enriched with pebbles up to 8 mm in diameter. Note high angle of dip of cross-laminae in upper right of sketch. This cross-stratification resulted probably from shearing of freshly deposited load that began to freeze

Bouma divisions. These structures are mainly represented by flat and wavy laminations (T_b and T_d; Tables 2 and 4). Ripple cross-lamination (T_c) and shale division (T_e) are rare. Flat lamination (T_b) is often picked out by coalified plant detritus (up to a few cm in size), usually of a coarser size than the associated mineral grains. Occasionally, the laminae are intercalated with thick (up to 30 cm), structureless portions composed of ungraded fine sandstone. Beds having large concentrations of plant matter are devoid of division T_c.

Table 4

Types and number of structural sequences within part T of 61 simple and pseudosimple beds. Structural divisions marked with numbers as in Tab. 2

Type of sequence	Number of beds	Type of sequence	Number of beds
9	3	9-10-9-11	1
9-7-9-7-9-11	3	9-10-11	11
9-7-9-10-11	2	9-10-11-12	2
9-7-9-11-12	1	9-11	25
9-7-9	2	9-11-12	3
9-11-9-11	5		

SEQUENCES OF STRUCTURAL DIVISIONS

The fluxoturbidite beds are highly diversified in respect to sedimentary structure assemblages and their internal stratigraphies (Tables 3 and 4; Figs. 12 to 14).

A monostructural aspect is revealed by 30% of the elementary normal beds and by part F present in 26% of the simple and pseudosimple beds. Some 75% among the monostructural elementary normal beds show ungraded textures. In the remaining 25% and in monostructurally developed part F of the simple and pseudosimple beds, the only structure recorded was normal grading. In 70% of the elementary normal beds and in part F of 75% of the simple and pseudosimple beds there occur two structural divisions at least. In these beds 28 structural sequences were encountered, differing in the frequency, type and vertical succession of structural divisions (Table 3).

A

									T_{b-e}		Σ
	1	2	3	4	5	6	7	8	9	10	
1	—	—	—	—	2	—	5	1	—	—	8
2	—	—	6	—	1	—	—	—	—	—	7
3	—	—	—	10	—	—	—	—	—	3	13
4	—	—	—	—	14	2	28	19	—	5	68
5	—	—	1	1	—	2	36	4	—	5	49
6	—	—	—	—	—	—	—	—	3	6	9
7	—	—	—	—	18	2	—	17	22	61	120
8	—	—	—	—	13	3	19	—	36	23	94
9	—	—	—	—	—	—	—	—	—	61	61
10	8	7	6	57	1	—	32	53	—	—	164
Σ	8	7	13	68	49	9	120	94	61	164	593

B

	1	2	3	4	5	6	7	8	9	10
1		-0.01	-0.02	-0.12	+0.17	-0.01	+0.42	-0.04	-0.10	-0.28
2	-0.01		+0.83	-0.12	+0.06	-0.01	-0.20	-0.16	-0.10	-0.28
3	-0.01	-0.01		+0.65	-0.08	-0.01	-0.21	-0.16	-0.10	-0.05
4	-0.01	-0.01	-0.02		+0.11	+0.01	+0.18	+0.10	-0.12	-0.31
5	-0.01	-0.01	-0.01	-0.10		+0.02	+0.51	-0.01	-0.11	-0.30
6	-0.01	-0.01	-0.02	-0.12	-0.08		-0.20	-0.16	+0.23	+0.38
7	-0.02	-0.01	-0.03	-0.14	+0.07	-0.01		-0.06	+0.05	+0.16
8	-0.02	-0.01	-0.03	-0.14	+0.04	+0.01	-0.04		+0.26	-0.08
9	-0.01	-0.01	-0.02	-0.13	-0.09	-0.02	-0.22	-0.18		+0.69
10	+0.03	+0.03	+0.01	+0.12	-0.11	-0.02	-0.02	+0.10	-0.14	

C

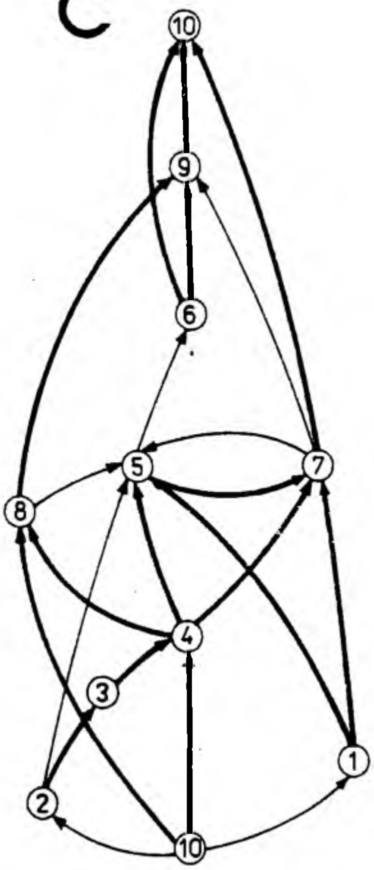


Fig. 11. Summary of vertical transitions of structural divisions in 164 fluxoturbidite beds, showing transition probability matrix (*A*), difference matrix between expected and observed probabilities (*B*) and transition flow diagram derived from difference matrix (*C*). Thick line denotes transitions that occur with probability larger than 0.1 from expected value; thin line corresponds to probability difference falling between 0.03 and 0.1. Structural divisions: *1* — large-scale cross-stratified sandstone and conglomerate; *2* — inversely graded conglomerate; *3* — homogeneous conglomerate; *4* — normally graded conglomerate; *5* — horizontal laminae composed of fine-sand and pebble-enriched bands; *6* — sandstone with dish structures; *7* — homogeneous sandstone; *8* — normally graded sandstone; *9* — Bouma T_{b-e} sequence; *10* — bed boundary

The most common are low-diversified sequences, commencing either with normally graded conglomerate or sandstone, or with homogeneous division, which in the simple and pseudosimple beds are followed upwards by the Bouma T_{b-e} divisions (Tables 3 and 4; Fig. 11B).

Less common are sequences that begin with homogeneous or normally graded division which is overlain by horizontal fine-sand lamination, in turn followed upwards by ungraded or normally graded division. Other structural sequences are rare in the fluxoturbidite beds analyzed.

The structural development of the fluxoturbidite beds is largely dependent on the sediment texture. In general, the structural diversity decreases with decreasing grain size. The fluxoturbidite beds were therefore classified into three textural groups and preferred structural transitions established for each of these.

Group CS comprises beds commencing with a conglomerate layer, more than 30 cm thick, that includes over 20% of a bed thickness and contains clasts above 10 mm in size. Group PS comprises bed commencing with a conglomerate layer, up to 30 cm thick, that includes up to 20% of a bed thickness and contains little admixtures of clasts larger than 10 mm in diameter. Group S comprises sandstone beds devoid of gravel admixtures. The sedimentary structure assemblages for each of these groups are summarized in Table 5.

Table 5

Occurrence of structural divisions in conglomeratic (CS), pebbly sandstone (PS) and sandstone (S) fluxoturbidite beds

Structural divisions	CS	PS	S
Bouma divisions (T_{b-e})	F	A	F
Sandstone with dish-structures	R	R	R
Normally graded sandstone	C	A	A
Homogeneous sandstone	A	A	A
Horizontal fine-sand lamination	F	C	–
Cross-stratified pebbly sandstone	–	R	–
Normally graded conglomerate	A	F	–
Homogeneous conglomerate	A	–	–
Inversely graded conglomerate	R	–	–

A – abundant (> 50%), C – common (30–50%), F – frequent (10–30%), R – rare (< 10%).

Group CS (26% of all measured beds; Figs. 5,7 and 12; Pls. II:1 and III:1) includes beds that commence with either normally graded division (69.8%), or rarely inversely graded (16.3%), or homogeneous division (13.9%). The coarser the conglomeratic layer the more homogeneous is the ungraded division. Upwards there comes normally graded or ungraded sandstone division, or

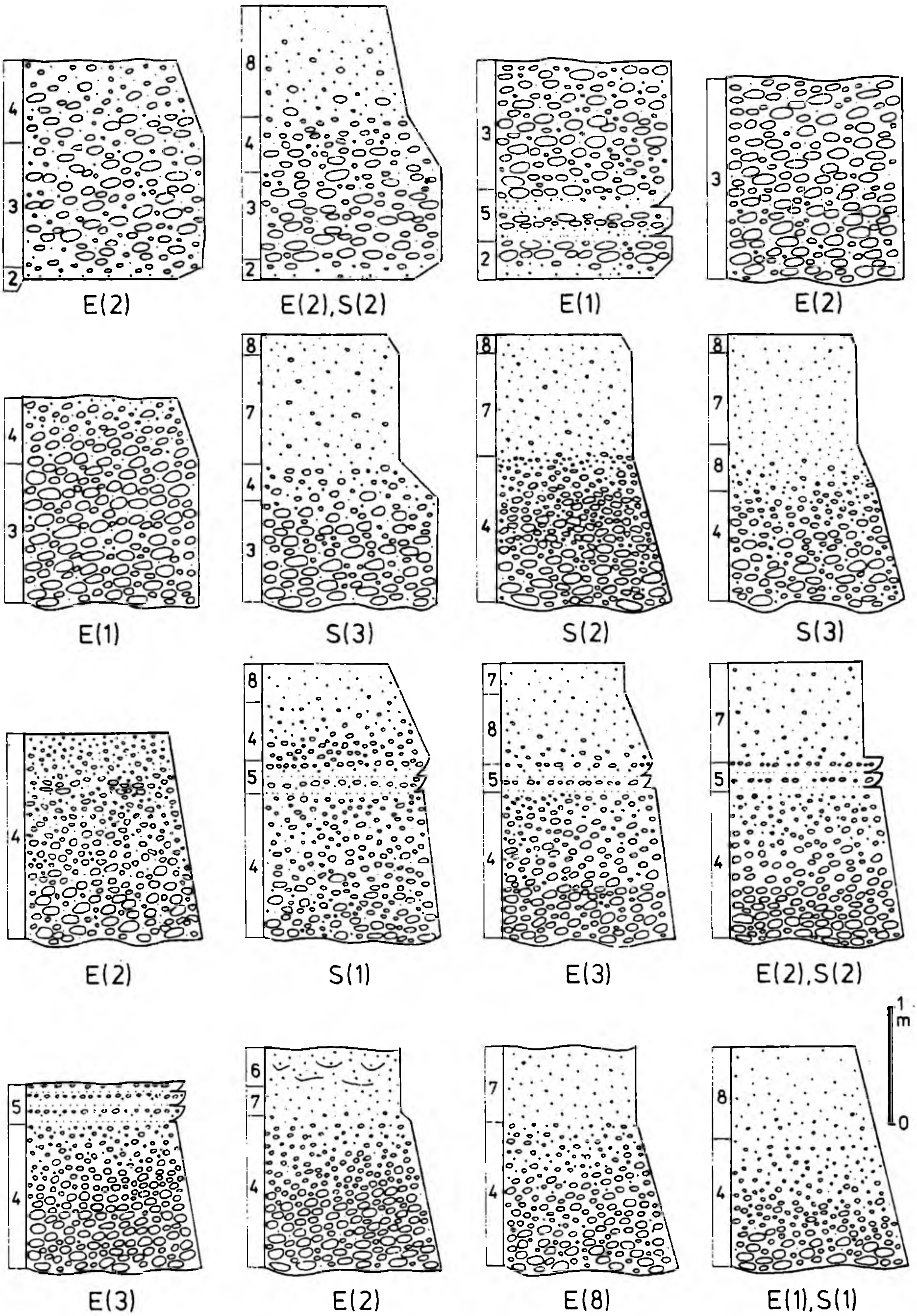


Fig. 12. Schemes showing vertical structural sequences observed in elementary normal beds and in part F of simple and pseudosimple beds of conglomeratic fluxoturbidites (group CS). Numbers in columns refer to divisions explained in Fig. 11; numbers in brackets denote frequency of beds. *E* – elementary normal bed; *S* – pseudosimple and simple bed

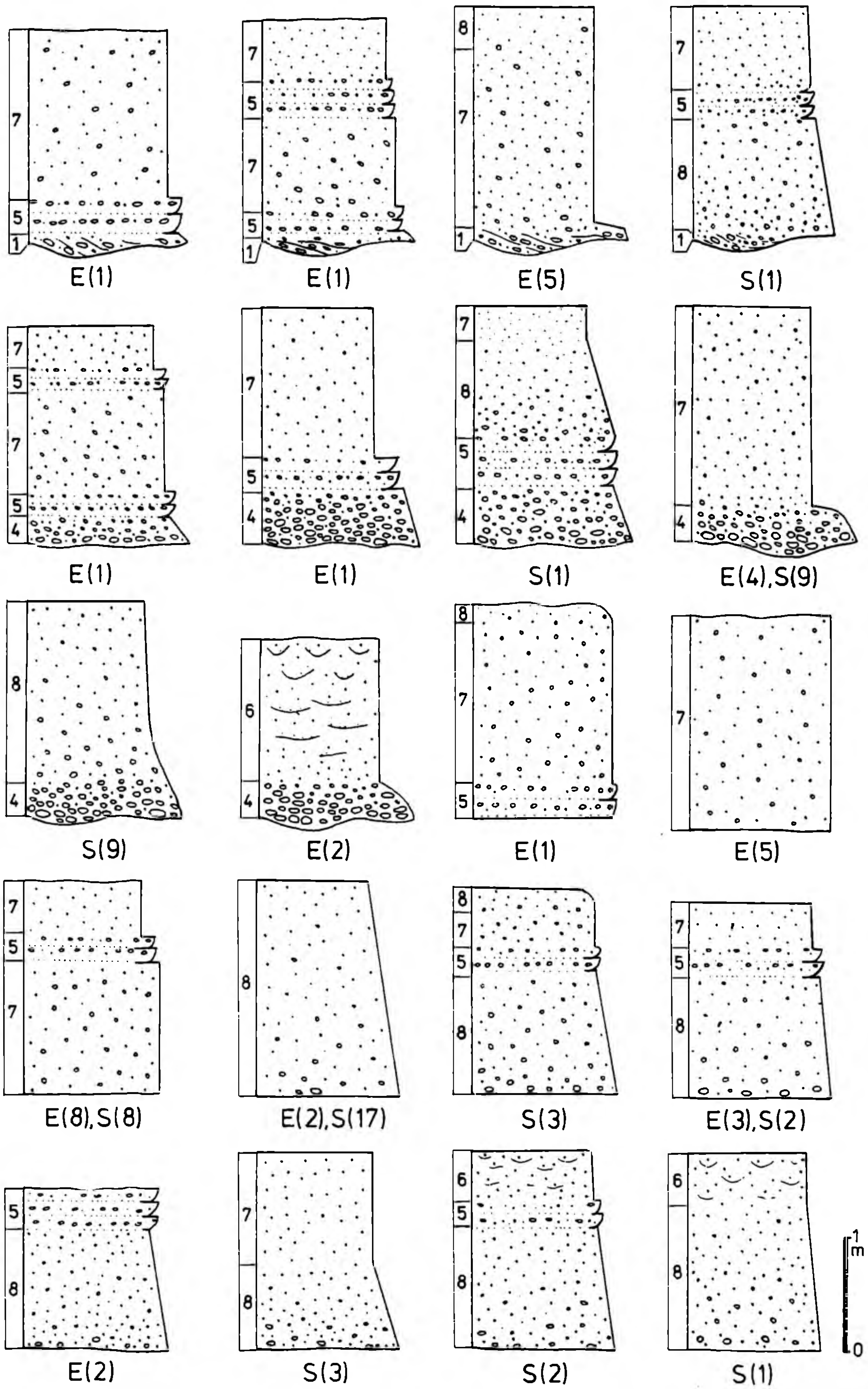


Fig. 13. Schemes showing vertical structural sequences observed in elementary normal beds and in part of simple and pseudosimple beds of pebbly sandstone fluxoturbidites (group MR). For explanation of letters and numbers see caption of Fig. 12

rarely (25.6%) there is an intervening zone of horizontal fine-sand lamination. In one bed such a zone is overlain by normally graded fine pebble conglomerate (Pl. II: 1). Two beds show dish structures in a sandstone interval. The simple and pseudosimple beds of group CS are capped by part T that commonly displays Bouma T_{bd} divisions.

Group PS (56% of all measured beds; Figs. 8 and 13; Pls. I and II: 2) include beds that begin most commonly (67.4%) with normally graded pebbly sandstone or fine pebble conglomerate. Rarely (23%) there is an ingraded pebbly sandstone. Eight beds (8.7%) show large-scale cross-stratification near the base (Pl. III: 2; Figs. 8 and 9). One bed commences with horizontal fine-sand lamination. Usually, such lamination appears in the pebble-depleted, middle and upper levels of the PS beds (39%). In the topmost parts of the beds there occurs homogeneous or normally graded division. In seven beds (8%) such divisions display dish structures. The simple and pseudosimple beds are capped by part T that usually displays Bouma T_{bd} divisions.

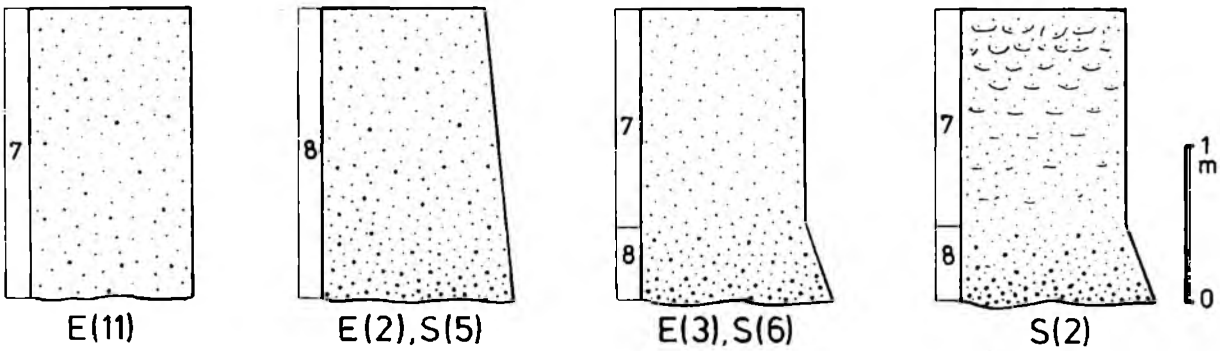


Fig. 14. Structural sequences observed in sandstone fluxoturbidites (group S). For explanation of letters and numbers see caption of Fig. 12

Group S (18% of the measured beds; Figs. 6 and 14) comprises beds composed of sandstone that is homogeneous or normally graded and is capped by a thin shale layer. Normal grading is best discernible in basal levels of the beds. Seven beds (24) show normal grading extending throughout the entire bed thickness. Two beds reveal dish structures in a graded division. Part T exhibits the Bouma T_{b-e} divisions.

LATERAL VARIABILITY OF THE FLUXOTURBIDITE BEDS

Lateral changes are most remarkable in the CS beds, manifesting particularly well in sections perpendicular to local palaeoflow directions. Such changes are commonly taking place within a distance of a few m (Fig. 13). A homogeneous or graded deposit rapidly passes laterally into a horizontally laminated one (Figs. 5 and 7); random clasts fabrics give way to more ordered configurations. Common are abrupt changes in gravel contents (Figs. 5 and 15).

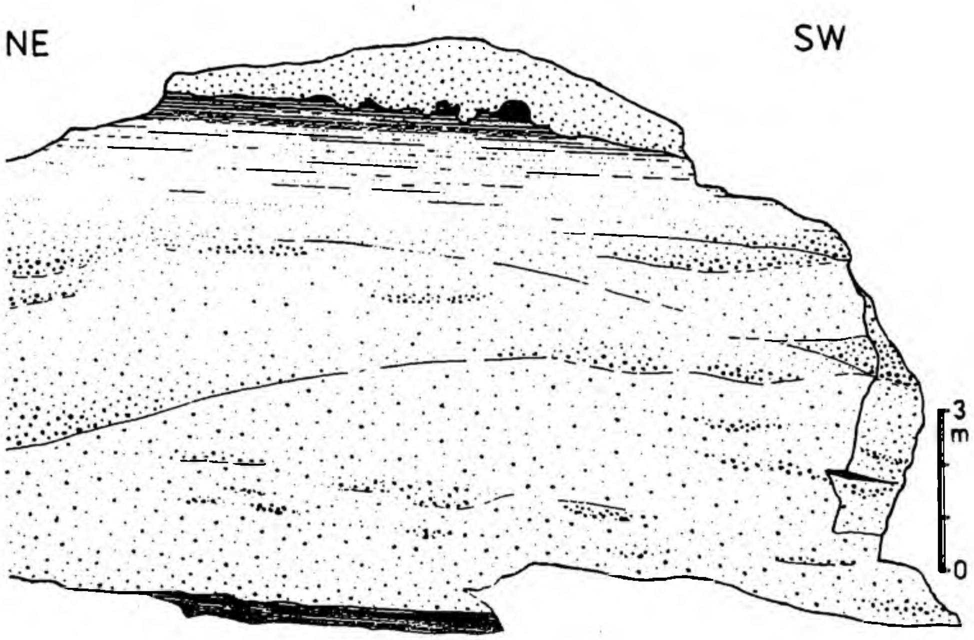


Fig. 15. Field example of composite bed showing extremely complex internal organization; quarry at Kąśna. Locality No. 7 in Fig. 1. Some conglomeratic lenses show troughcross-stratification. Topmost part of bed exhibits unsually thick parallel-laminated division (T_b) enriched in coalified plant matter

Similar lateral variability of coarse resedimented deposits was described by Aalto (1976), Johnson and Walker (1979), Winn and Dott (1979), Cazzola and others (1981), Hein and Walker (1982), Surlyk (1984), and Massari (1984).

Little is known about downflow variations within fluxoturbidite deposits. In general, fluxoturbidite lithosomes show a parallel alignement to the regional palaeoflow dispersal (Książkiewicz *et al.*, 1962). Lithosomes dominated by the sandstone fluxoturbidites (group S) tend to show a constant development over wide areas. They either rapidly die out within Mutti and Ricci Lucchi's (1975) Facies D and G (e.g. in the Kliwa Sandstone), or gradualy pinch out within Facies C (Krosno Beds – Wendorff, 1986). In lithosomes dominated by conglomeratic and pebbly sandstone fluxoturbidites (CS and PS) there is a downflow size decrease of coarse fraction, accompanied by a decline in the conglomerate contents over a distance of 100 km, followed subsequently by termination of the fluxoturbidite lithosomes over a distance of a few km within Mutti and Ricci Lucchi's Facies G and D. Similar rapid facies changes within resedimented conglomerates were reported by Surlyk (1984).

It should be noted, however, that the decrease in size and amount of coarse fraction is not always regular and obvious (Leszczyński, 1981, 1986; Fig. 2B, C). In some instances, such an irregularity may be due to that the lithosomes were fed from several sources. However, there are too few data to support this notion. The available evidence does not support suggestions made by Walker (1975), Aalto (1976) and Lowe (1982) on regular downflow facies changes within turbidite deposits (comp. Surlyk, 1984).

IDEAL AND MODAL BEDS

The generalized textural-structural development for each of the three fluxoturbidite bed groups was illustrated in the form of an ideal bed and a modal bed (Fig. 16). The ideal bed shows all structural divisions encountered in a given bed group. The modal bed visualizes the most typical structural sequence for a group.

In the sequential analysis (Tables 3 and 4; Fig. 11) the following divisions within the "proper" fluxoturbidite (F) were considered:

F1 – basal conglomerate with inverse grading;
F2 – normally graded or homogeneous conglomerate occurring in layers thicker than 30 cm;
F3 – cross-stratified conglomerate or pebbly sandstone;
F4 – homogeneous or normaly graded pebbly sandstone;
F5 – sandstone or microconglomerate with horizontal fine-sand laminae;
F6 – homogeneous or normally graded sandstone, locally with dish structures.

Other structural elements considered in the analysis comprise the divisions of Bouma classical turbidite (T). Graded and ungraded intervals of granulometrically similar sediments were lumped together in one structural division (F2 and F3), because their separation is often impossible in the field, and because their mode of deposition is the same (see Pickering *et al.*, 1986).

The ideal beds generated for the CS and PS groups (Fig. 16) appear to represent exceptionally rare real cases because of the scarcity of some structural divisions. The ideal bed of the S group corresponds in its unit F developments to the modal bed of this group. The ideal PS and S beds correspond essentially to higher parts of the ideal CS bed.

IDEAL FLUXOTURBIDITE BEDS AND THE FLUXOTURBIDITE BED MODEL OF ŚLĄCZKA AND THOMPSON

The fluxoturbidite bed model generatered by Ślączka and Thompson (1981; Fig. 17A) corresponds in general to the ideal CS bed, though it lacks the basal inversely graded division distinguished here (Fig. 17A). The model includes two flat laminated intervals: the lower interval delineated by gravelly laminae and the upper one composed of sand laminae. These intervals are interrupted by a non-laminated sandstone which was ascribed to the lower interval. The present observation does not support validity of such subdivision. Commonly, the gravelly laminae are associated with sand laminae and become less marked upwards. This is not a rule, however, and normally there are only fine-sand laminae present in upper half of a bed. Ślączka and Thompson's model contains also a division comparised of mud-clast bearing sandstone. Such a division may occupy, however, different levels within a bed (comp. Mutti & Nilsen, 1981). In general, the smaller the mud clasts the higher the position

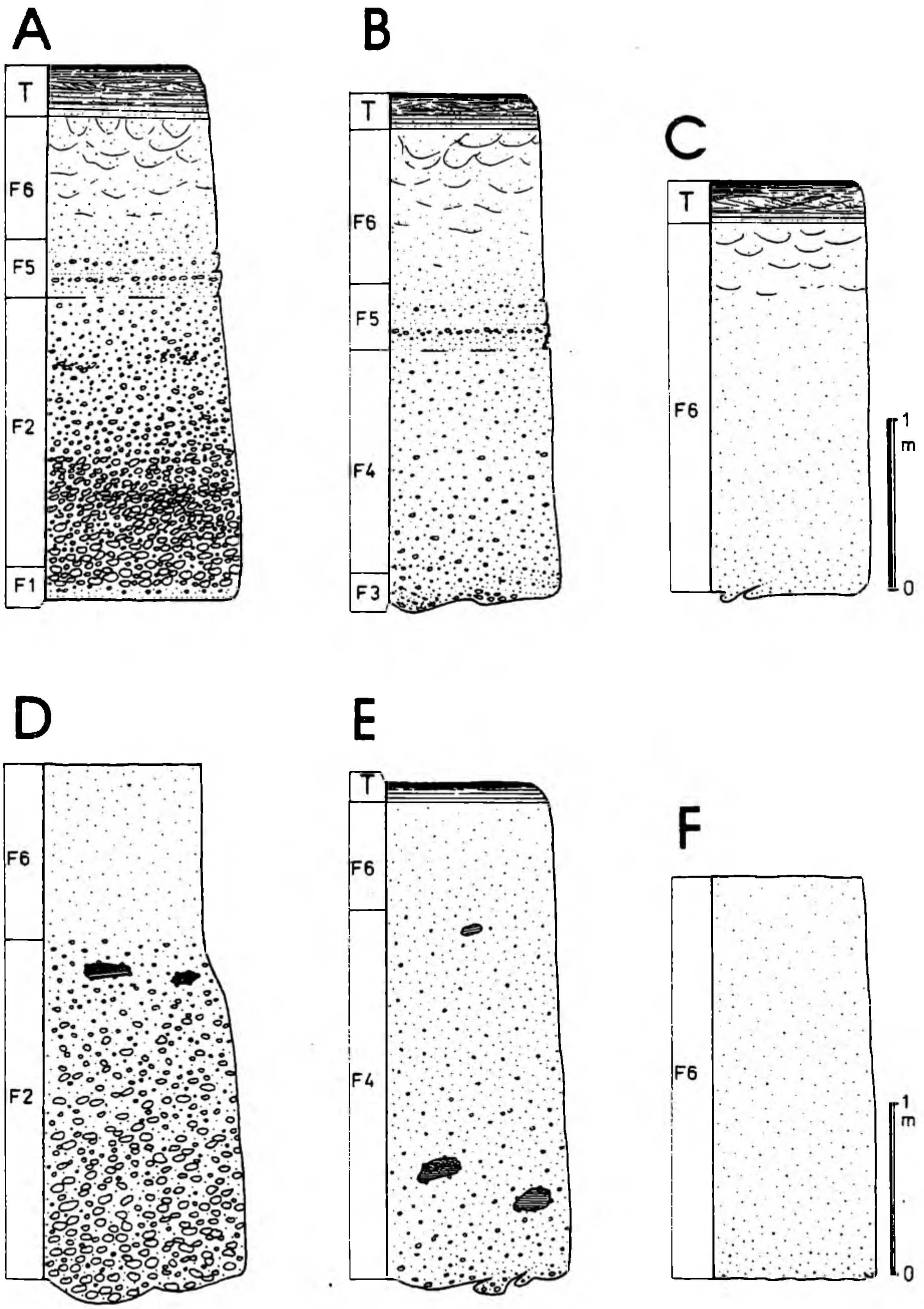


Fig. 16. (*A-C*) Ideal bed models for conglomeratic (*A*), pebbly sandstone (*B*) and sandstone (*C*) fluxoturbidites. (D-F) Modal beds for conglomeratic (*D*), pebbly sandstone (*E*) and sandstone (*F*) fluxoturbidites. For explanation of symbols of structural divisions, see Table 6

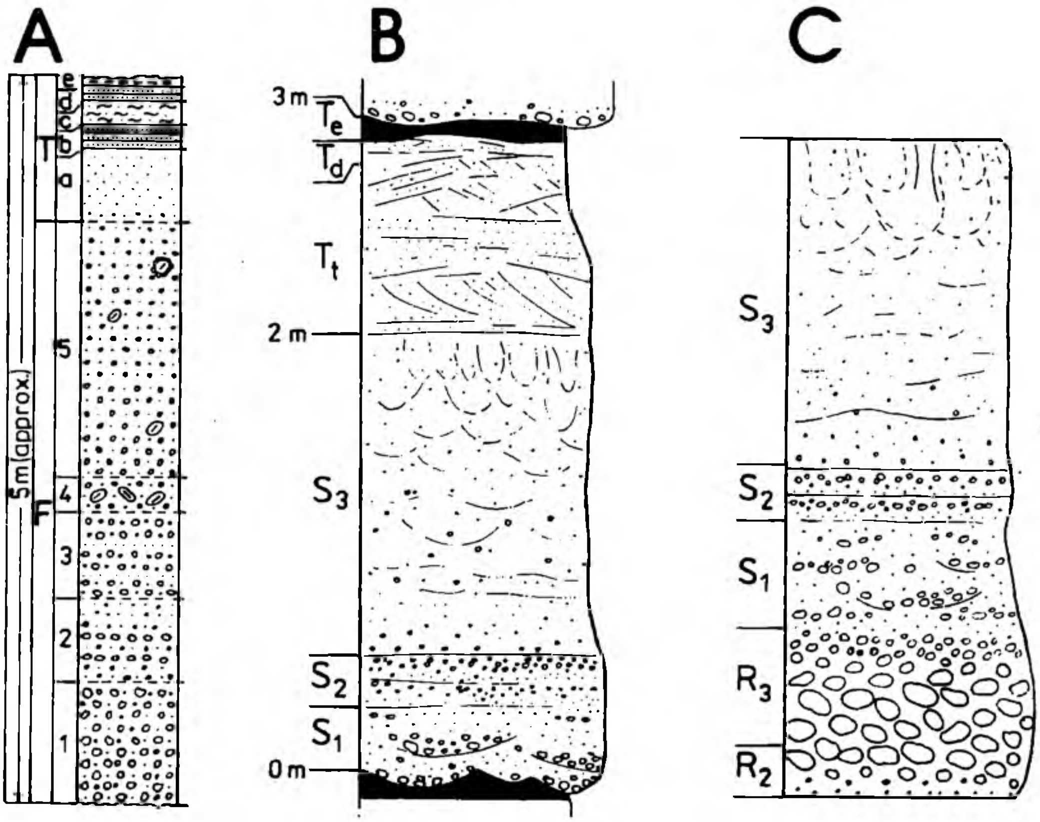


Fig. 17. (*A*) Fluxoturbidite bed model of Ślączka and Thompson (1981). (*B*, *C*) High-density turbidite bed models of Lowe (1982) for deposits of sandy (*B*) and gravelly (*C*) turbidity currents

assumed by them within a bed. According to Lowe (1982) the non-laminated sandstone lying beneath the Bouma T_{b-e} sequence can be related genetically to an underlying sediment rather than to an overlying one, as it is implied in the model by Ślączka and Thompson. This model is not representative for the PS beds which are the most typical for the fluxoturbidites. It does not include large-scale cross-stratification, dish structures and, in addition, pebbly sandstone division characteristic for the PS beds is situated above laminated division.

POSITION OF FLUXOTURBIDITES WITHIN CLASSIFICATIONS OF MASS-FLOW DEPOSITS

Fluxoturbidites are coarse-grained resedimented deposits. In descriptive schemes of such deposits they fall within Facies A and B (Mutti & Ricci Lucchi, 1972, 1975; Walker & Mutti, 1973; Pickering *et al.*, 1986). In terms of the classification by Pickering and others (1986) fluxoturbidites correspond mainly to Facies A1.4, A2.7 and B1.1, and subordinately to Facies A1.1, A2.1-6 and C2.1. The above schemes fail to include pebbly sandstone and cross-stratified conglomerate divisions (F3) as well as normally graded sandstone devoid of T_{b-e} cappings (F6). The latter sandstone can be assigned to Facies C2.1, but not wholly, for this facies comprises sand-mud couplets. Position of a homogeneous sandstone with T_{b-e} cap is also unclear within the above classification. It can perhaps be included within Facies C2.1.

The analyzed fluxoturbidite beds, except those assembled in group S and the monostructural varieties, sequences F2F5 and F6T of the PS and CS groups, are falling into a number of facies in the scheme of Pickering and others (1986). This is an obvious disadvantage of this and other mass-flow deposit classifications in respect to fluxoturbidites. Facies distinguished in these classifications do not embody the entire bed laid down from a single flow.

In genetic classificatory schemes, fluxoturbidites correspond basically to the deposits of high-density turbidity currents (Lowe, 1982), and subordinately to the deposits of cohesionless debris flows and fluidized flows. All fluxoturbidite beds documented here can be genetically related to high-density turbidity currents, including beds of group S whose genetic significance is not entirely clear in terms of Lowe's (1982) model. However, their high-density turbidite origin is beyond doubt in light of experimental and field results by Middleton (1967) and Hein (1982). The fluxoturbidite beds reveal all principal structural divisions of the Lowe sequence (Table 6), even so their development are somewhat different from those defined by Lowe. Division F3, distinguished here, corresponds only in part to Lowe's division S1, for it comprises single, isolated cross sets which probably have a different origin from that anticipated for S1. In some beds (Fig. 5) division F3 is similar to division R3b distinguished by Massari (1984) in his high-density turbidite bed model.

Table 6

Correlation between structural divisions distinguished in fluxoturbidites (this paper) and high-density turbidites of Lowe (1982)

Fluxoturbidite	High-density turbidite
T	T
F6	S_3
F5	S_2
F4	S_3
F3	S_1
F2	R_3
F1	R_2

Division F6 may be overlain by horizontal, slightly wavy laminae similar to those that occur near the top of Massari's (1984) divisions S3. This lamination was distinguished as T_b in the fluxoturbidite beds. Part T of the fluxoturbidite beds differs from part T in the Lowe sequence in lacking large-scale cross-stratification. In general, the fluxoturbidite beds are poorer in structures as compared to the high-density turbidite bed models.

The ideal conglomeratic fluxoturbidite bed (Fig. 16A) shows resemblance to the model bed of a gravelly turbidity current (Fig. 17C). It differs from the latter in lacking division S1 and in finer grain size (the coarsest pebbles rarely above 5 cm in diameter).

The ideal pebbly sandstone fluxoturbidite bed (Fig. 16B) corresponds texturally and structurally (except for the lack of cross-stratification in part T) to the model bed of a high-density sandy turbidity current (Fig. 17B). It differs from the latter in displaying two divisions corresponding to S3; the lower one (S4) situated below horizontal-laminated division (F5 – S2) and the upper (F6) occupying the position of S3 in Lowe's model.

The ideal sandstone fluxoturbidite bed (Fig. 16C) is analogous to the high-density turbidite S3T of Lowe (1982) and to the Bouma classical turbidite. It differs from the classical turbidite bed in displaying low thickness of T_{b-e} sequence and in the dominance of division T_a (F6).

The ungraded conglomeratic fluxoturbidite beds correspond to the deposits of both high-density turbidity currents (R3 in the Lowe sequence) and cohesionless debris flows (Lowe, 1982; Nemec & Steel, 1984). The homogeneous sandstone fluxoturbidite beds (S3 in Lowe sequence) are similar to the model beds of liquefied flows (Lowe, 1982; Surlyk, 1984), although water-escape structures are poorly developed in the former beds.

DEPOSITION OF FLUXOTURBIDITES

ELEMENTARY AND SIMPLE BEDS

The fluxoturbidite beds show features compatible with deposition from high-density turbidity currents *sensu* Lowe (1982). Such origin may also be ascribed to ungraded monostructural beds (Hein, 1982; Pickering *et al.*, 1986), but other alternatives are likely too. Ungraded conglomerates may have been laid down from cohesionless debris flows (Nemec & Steel, 1984), and homogeneous sandstones from fluidized flows. According to Surlyk (1984), ungraded sandstones may be deposited from high-density turbidity currents which during deposition become transitional to fluidized flows. The scarcity of water-escape structures in such sandstones has been attributed by Surlyk (1984) to the coarse-grained nature of this sediment.

The simple and pseudosimple fluxoturbidite beds were formed in two basically different stages involving deposition from a high-density suspension succeeded by sedimentation from a residual low-density suspension (Ślączka & Thompson, 1981; Leszczyński, 1981; Lowe, 1982). The first stage resulted in part T of a fluxoturbidite bed, the second one gave rise to part T of a simple or pseudosimple bed. The elementary normal beds were laid down from high-density suspensions only.

The deposition from a high-density suspension is taking place (Lowe, 1982) through (1) mass settling, (2) freezing and shearing out the basal load from a flow, and (3) settling of individual grains from traction. Mass settling from suspension was the main depositional agent for the fluxoturbidite beds (Table

Table 7

Summary of depositional mechanisms associated with emplacement of conglomeratic (CS), pebbly sandstone (PS) and sandstone (S) fluxoturbidite beds from high-density suspensions

Depositional mechanism	Number of beds
CS beds	
MS1	23
MS1?	2
MS1-SO-MS1	8
MS1-SO	3
MS2	6
MS2-SO-MS1	1
PS beds	
MS	47
MS?	9
MS-SO	2
MS-SO-MS	28
SO-MS	3?
TS-SO-MS-SO-MS	1
TS-SO-MS	1
?MS-SO-MS	1
S beds	
MS	29

MS – mass-settling from high-density suspension; MS1 – as above plus traction; SO-freezing and shearing out the basal load from a flow; TS – settling of individual grains from traction.

7), giving rise to non-laminated, ungraded or normally graded divisions (F2, F4 and F6). If the deposited sediment was dragged on the bottom before the final freezing, inversely graded division originated (F1+F2). For majority of the fluxoturbidite beds deposition had began and ended with mass settling from a high-density suspension. Water-escape structures were associated with final depositional stages (Lowe & LoPiccolo, 1974; Lowe, 1982).

The sorting and degree of vertical size fractionation of a suspension-mass settling deposit depended mainly on the primary grain-size range and the sorting ability of a flow. The latter was in turn controlled by density changes within a flow, slope gradients, duration and manner of initiation of a flow. The mass deposition from suspension was associated with tangential shear stresses imposed on the bottom by the slowing suspension load, particularly strong ones within depressions of the bottom. This resulted in the formation of a series of inclined shear planes which are delineated by tangential fine-sand laminae present near the base of some beds (Fig. 10). The laminae originated from grain-size segregation through dispersive pressure acting on grains in the zones of shear (Bagnold, 1954; Sanders, 1965; Fisher, 1971; Carter, 1975; Postma *et al.*, 1983).

Deposition due to freezing and shearing out the basal load from a flow resulted in the formation a horizontally to slightly wavy laminated sediment (F5) composed of alternating thin, fine-sandstone and thicker, pebbly sandstone or microconglomeratic laminae. This particular kind of deposition from mass flows was first envisioned by Sanders (1965), and subsequently advocated by Carter (1975). Lowe (1982) suggested that during a slow-suspension settling of grains from a flow, these become concentrated near the bed and shearing imposed by the overlying flow may produce inverse grading within this moving grain layer which, itself, corresponds to the traction carpet of Dżułyński and Sanders (1962).

Effects of such deposition appear rarely in the fluxoturbidite beds analysed. The rare occurrence of inverse grading above the fine-sand laminae suggests that division F5 distinguished here, owes its origin to a rapid freezing of the basal moving grain layer which was not sheared enough to produce a distinct inverse grading. The thickness of such layers is probably directly correlated to the rate of feeding of the traction carpet with grains falling down from the overlying suspension. In zones of abrupt wedging out of the rapidly deposited sediment, layers laid down through shearing out and freezing from low-angle cross sets (Figs. 5 and 9). It is also likely that such cross sets originated due to migration and aggradation of antidunes beneath a supercritical flow (Hiscott & Middleton, 1979, p. 323; Colella, 1980).

The large-scale through cross-stratification in pebbly sandstone, present near the base of some beds (Fig. 8), reflects traction deposition between pulses of mass-settling from high-density sespensions. However, such tractional-flow conditions only sporadically accompanied the emplacement of the fluxoturbidite beds. Similarly, deposition from residual low-density suspensions was sporadic also. It involved tractional emplacement of muddy-sandy deposits, usually displaying the Bouma T_{bcd} sequence. The formation of division T_c was hindered by the common concentration of plant matter, commonly of larger sizes than the associated siliciclastic detritus. When the residual suspension was rich in sand-sized load, the tractional episodes were interrupted by a rapid suspension-mass settling, giving rise to homogeneous sand layers intercalated with laminated division T_b (comp. Lowe, 1982).

COMPOSITE BEDS

The composite beds resulted from surging flows (comp. Lowe, 1982, fig. 11B), or amalgamation of several flows (Leszczyński, 1986), or both. Those formed by amalgamation of individual sedimentation units are highly variable laterally. Within a distance of a few m, they split into several beds which, traced further laterally, commonly rejoin rapidly. The composite beds which originated from surging flows fine typically upwards and show diffuse contacts between elementary beds. Figure 15 shows an example of such composite bed which originated from a number small depositional pulses related to a single flow. The last pulse involved deposition from a residual suspension and resulted in flat laminated sand (T_b) passing upwards into mud (T_d).

The very thick (tens of m or more) composite beds of surging flow origin correspond to megaturbidites (Johns *et al.*, 1981; Labaume *et al.*, 1983; Marjanac, 1985; Kleverlaan, 1987), whose origin can be linked to large-scale failure and gravity emplacement of tremendous quanitities of clastic material. Some differences between these fluxoturbidites and the megaturbidites stem from the textural inhomogeneity of the former. The coarse sand making-up the bulk of the fluxoturbidite beds was particulary prone to dispersion during transportion into a number of distinct plumes (surges) (comp. Hendry, 1973; Andresen & Bjerrum, 1967; Kleverlaan, 1987).

FLUXOTURBIDITES VS. HIGH-DENSITY TURBIDITES: DIFFERENCES IN DEPOSITIONAL PROCESSES

Deposition of the fluxoturbidite beds was basically similar to that inferred by Lowe (1982) for the model beds of high-density turbidites. It proceeded into two steps – the first involving emplacement of the gravelly to coarse-sand load, the second dominated by sedimentation of finer-size grades.

The fluxoturbidites were laid down mainly through the process of suspension-mass settling. Tractional deposition was of lesser importance, and only sporadically involved the coarsest load. Deposition within large-scale bedforms did not occurred, in striking contrasts to the prediction implied in Lowe's model of high-density turbidites (division (T_t). The rare occurrence of dish structures in the analyzed fluxoturbidite beds is also difficult to explain in terms of Lowe's (1982) model. It is likely that this was caused by a somewhat different mode of deposition of these beds.

The features of the fluxoturbidites indicate deposition from rapidly waning flows. The high-density turbidite models are on the other hand compatible with flows which dropped their load more gradually. Most of the fluxoturbidite beds could have been deposited from flows of higher densities than those characteristic of typical high-density turbidity currents, possibly from flows close in rheology to cohesionless debris flows and fluidized flows. The latter origins can be assigned to homogeneous (ungraded, non-laminated) fluxoturbidite beds.

The deposition of the CS and PS fluxoturbidite beds corresponding to the gravelly and sandy high-density turbidites, respectively, was nearly always (90% of the beds) initiated by suspension-mass settling. In Lowe's model the deposition from the high-density gravelly turbidity current begins with freezing of traction carpet, while that from the sandy current with dropping some of the suspended load, followed by tractional bed reworking. The CS bed do not record the traction phase that is marked in Lowe's model to separate the deposition of gravelly and sand loads. The beds show most frequently evidence of rapid deposition of gravels from suspension, followed by emplacement of traction carpets, and this, succeded by suspension-mass settling of sand.

The formation of the PS beds was often associated with two pulses of suspension-mass settling interrupted by a phase of freezing and shearing out of the basal layers from a flow. In contrast, the corresponding Lowe bed models show one mass-settling phase which ends deposition from dense suspension (division S3).

The S fluxoturbidite beds, representing deposits which do not fit easily into the Lowe bed models of high-density turbidites, are similar to the deposits of classical turbidity currents. Lowe (1982, p. 279) classified similar beds as normal turbidites. However, such beds differ from the normal turbidites in being dominated by a single, thick sandstone division pointing to deposition from dense suspensions or fluidized flows. Some of very thick beds are capped by Bouma T_{b-e} sequences, normally ocuppying no more than a few per cent of the bed thickness. These beds also originated due to rapid mass settling from dense suspensions and the final depositional stage was only to a little degree affected by slow suspension settling from a diluted flow.

SUMMARY AND CONCLUSIONS

It is concluded from the foregoing disccussion that the coarse resedimented deposits called fluxoturbidites are the product of deposition from high-density turbidity currents *sensu* Lowe (1982), and subordinately from fluidized flows and density-modified grain flows (cohesionless debris flows). The three fluxoturbidite bed models distinguished here differ from the high-density turbidite facies models of Lowe (1982) in the narrower array of sedimentary structures and in somewhat different structural organization. The features of the fluxoturbidite beds point to deposition in conditions which did not promote the full development of turbidity currents. The widespread evidence of sedimentation from rapidly waning flows suggests an uneven bottom of the receiving basins and possibly a low gradients of the surrounding slopes, which both could have prevented the turbidity currents to develop speeds great enough to become independent from the underlying topography. The rapid deposition could also have enhanced the bottom relief through of convex-upward sediment bodies.

Part of the analyzed fluxoturbidite beds may have originated through redeposition within a basin. This is indicated by the presence of ungraded, non-laminated sandstone and conglomerate beds within the distal segments of fluxoturbidite lithosomes. Such beds are compatible with deposition from fluidized flows or density-modified grain flows which are known to be steady over short distances only. Hence, the flows which laid down these beds must have been initiated within a basin. This, in turn, indicates an unstable nature of the floor of the fluxoturbidite basins (comp. Koszarski & Koszarski, 1985).

The term fluxoturbidite appears to be useful one because it is applicable both to the deposits forming separate beds and to those which coexist within a single bed and, because it comprises deposits of different origin ranging from high-density turbidity currents, fluidized flows to density-modified grain flows. As shown before, all these processes are intimately associated, often within a single event, and result in an essentially uniform and easily identifiable depositional product. The term fluxoturbidite encompasses also deposits which are placed within different descriptive facies and the usage of such many descriptive terms is often difficult, because single bed may be composed of sediments belonging to different facies.

In light of the foregoing analysis it is proposed to add to the existing facies models of high-density turbidites (Lowe, 1982) the ideal bed constructed here for the sandstone fluxoturbidites (group S). Such fluxoturbidite beds differ from the sandstone classical turbidites in showing very thick massive division overlain by thin T_{b-e} sequence.

The nature of lateral transitions between fluxoturbidites and turbidites remains unclear. The fluxoturbidite lithosomes appear to rapidly wedge out within turbidite Facies C2, 3, 4 and D of Pickering and others (1986).

REFERENCES

Aalto, K. R., 1976. Sedimentology of a mélange: Franciscan of Trinidad California. *J. Sediment. Petrol.*, 46:913–929.

Andresen, A. & Bjerrum, L., 1967. Sildes in subaqueous slopes in loose sand and silt. In: A. F. Richards (ed.), *Marine Geotechnique. Proc. Int. Research Conf. on Marine Geotechnique*, p. 221–239, Urbana.

Bagnold, R. A., 1954. Experiments on gravity-free dispersion of large solid spheres in a Newtonian fluid under shear. *Proc. Roy. Soc. London*, Ser. A, 225:49–65.

Bouma, A. H., 1962. *Sedimentology of some flysch deposits.* Elsevier, Amsterdam, 168 pp.

Carter, R. M., 1975. A discussion and classification of subaqueous mass-transport with particular application to grain-flow, slurry-flow, and fluxoturbidites. *Earth Sci. Rev.*, 11:145–177.

Cazzola, C., Fonnesu, F., Mutti, E., Rampone, G., Sonnino, M. & Vigna, B., 1981. Geometry and facies of small, fault controlled deep-sea fan systems in a transgressive depositional setting (Tertiary Piedmont basin, Northwestern Italy). In: F. Ricci Lucchi (ed.), *Excursion Guidebook, International Association of Sedimentologists. 2nd European Regional Meeting*, Bologna, p. 7–53.

Colella, A., 1980. Medium-scale tractive bedforms and structures in Gorgolione Flysch (Lower Miocene, Southern Apennines, Italy). *Boll. Soc. Geol. Ital.*, 98:483–494.

Dżułyński, S., Książkiewicz, M., Kuenen, P. H., 1959. Turbidites in flysch of the Polish Carpathian Mountains. *Bull. Geol. Soc. Am.*, 70:1089–1118.

Dżułyński, S. & Sanders, J. E., 1962. Current marks on firm mud bottoms. *Trans. Connecticut Acad. Arts and Sciences*, 42:57–96.

Fisher, R. V., 1971. Features of coarse-grained, high-concentration fluids and their deposits. *J. Sediment. Petrol.*, 41:916–927.

Hein, F. J., 1982. Depositional mechanisms of deep-sea coarse clastic sediments, Cap Enragé Formation, Québec. *Can. J. Earth Sci.*, 19:267–287.

Hein, F. J., & Walker, R. G., 1982. The Cambro-Ordovician Cap Enragé Formation, Québec, Canada: conglomeratic deposits of a braided submarine channel with terraces. *Sedimentology*, 29:309–329.

Hendry, H. E., 1973. Sedimentation of deep-water conglomerates in Lower Ordovician rocks of Quebec – composite bedding produced by progressive liquefaction of sediment. *J. Sediment. Petrol.*, 43:115–136.

Hiscott, R. N. & Middleton, G. V., 1979. Depositional mechanics of thick-bedded sandstones at the base of a submarine slope, Tourelle Formation, Ordovician, Québec, Canada. *Soc. Econ. Paleontol. Miner., Spec. Publ.*, 27:307–326.

Johnson, B. A. & Walker, R. G., 1979. Paleocurrents and depositional environments of deep-water conglomerates in the Cambro-Ordovician Cap Enragé Formation, Québec Appalachians. *Can. J. Earth Sci.*, 16:1375–1387.

Johns, D. R., Mutti, E., Rossell, J. & Séguret, M., 1981. Origin of a thick redeposited carbonate bed in the Eocene turbidites of the Hecho Group, south-central Pyrenees, Spain. *Geology*, 9:161–164.

Kleverlaan, K., 1987. Gordo megabed: a possible seismite in a Tortonian submarine fan, Tabernas basin, Province Almeria, southeast Spain. *Sediment. Geol.*, 51:165–180.

Koszarski, L. & Koszarski, A., 1985. Profiles of central zone of the Skole Unit east of Wisłok River. In: L. Koszarski (ed.), *Geology of the Middle Carpathians and the Carpathian Foredeep. Carpatho-Balkan Geol. Assoc. XIII Congress, Cracow, Poland 1985. Guide to Excursion 3*, p. 100–105, Geol. Institute.

Książkiewicz, M. (ed.), 1962. *Geological Atlas of Poland Stratigraphic and Facial Problems, Fasc. 13.* Instytut Geologiczny, Warszawa.

Kuenen, P. H., 1958. Problems concerning source and transportation of flysch sediments. *Geol. Mijnbouw.*, 20:329–339.

Labaume, P., Mutti, E., Seguret, M. & Rossell, J., 1983. Megaturbidites carbonatées du basin turbiditique de l'Eocéne inférieur et moyen sud-pyrénéen. *Bull. Soc. Geol. France*, 25:927–941.

Leszczyński, S., 1981. Ciężkowice Sandstones of the Silesian Unit in Polish Carpathians: a study of coarse-clastic sedimentation in deep-water (In Polish, English summary). *Ann. Soc. Geol. Pol.*, 51:435–502.

Leszczyński, S., 1985. Shear-stratification in fluxoturbidites (Ciężkowice Sandstone, Polish Carpathians). *IAS 6th European Meeting, Lerida, Abstracts*, p. 597–598, Universita Autonoma, Barcelona, Spain.

Leszczyński, S., 1986. Depositional processes of fluxoturbidites, Ciężkowice Sandstone (Lower Paleogene) Silesian nappe, Polish Carpathians. *IAS 7th European Regional Meeting, Excursion Guidebook, Excursion No. B-7*, p. 114–121, Ossolineum, Wrocław.

Lowe, D. R., 1982. Sediment gravity flows: II. Depositional models with special reference to the deposits of high-density turbidity currents. *J. Sediment. Petrol.*, 52:279–297.

Lowe, D. R. & LoPiccolo, R. D., 1974. The characteristics and origins of dish and pillar structures. *J. Sediment. Petrol.*, 44:484:501.

Marjanac, T., 1985. Composition and origin of the megabed containing huge clasts (flysch formation, middle Dalmatia, Yugoslavia). *IAS 6th European Regional Meeting, Lerida, Abstracts*, p. 270–273, Universita Autonoma, Barcelona, Spain.

Massari, F., 1984. Resedimented conglomerates of a Miocene fan-delta complex, southern Alps, Italy. In: E. H. Koster & R. J. Steel (eds.) *Sedimentology of gravels and conglomerates. Can. Soc. Petrol. Geol., Mem.*, 10:259–278.

Middleton G. V., 1967. Experiments on density and turbidity currents, part III. *Can. J. Earth Sci.*, 4:475–505.

Middleton, G. V. & Hampton, M. A., 1973. Sediment gravity flows: mechanics of flow and deposition. In: G. V. Middleton & A. H. Bouma (eds.), *Soc. Econ. Paleontol. Miner. Pacific Coast Section, Short Course Notes*, p. 197–218, Anaheim.

Middleton, G. V. & Hampton, M. A., 1976. Subaqueous sediment transport and deposition by sediment gravity flows. In: D. J. Stanley & D. J. Swift (eds.), *Marine sediment transport and environmental management*, p. 197–218, Wiley Interscience, New York.

Mutti, E. & Nilsen, T. H., 1981. Significance of intraformational rip-up clasts in deep-sea fan deposits. In: *IAS 2nd European Regional Meeting, Bologna, Italy, Abstracts*, p. 117–119.

Mutti, E. & Ricci Lucchi, F., 1972. Le torbiditi dell' Appenino settentrionale: introduzione all' analisi di facies. *Mem. Soc. Geol., Ital.*, 11:161–199.

Mutti, E. & Ricci Lucchi, F., 1975. Turbidite facies and associations. In: E. Mutti *et al.* (eds.), *Examples of turbidite facies and associations from selected formations of the Northern Apennines. Field Trip Guidebook A-11, 9th IAS Congress, Nice*, p. 21–36.

Nemec, W. & Steel, R. J., 1984. Alluvial and coastal conglomerates: their significant features and some comments on gravelly mass-flow deposits. In: E. H. Koster & R. J. Steel (eds.), *Sedimentology of gravels and conglomerates. Can. Soc. Petrol. Geol., Mem.*, 10:1–31.

Pickering, K., Stow, D., Watson, M. & Hiscott, R., 1986. Deep-water facies, processes and models: a review and classification scheme for modern and ancient sediments. *Earth Sci. Rev.*, 23:75–174.

Postma, G., Roep, T. B. & Ruegg, G. H. J., 1983. Sandy-gravelly mass flow deposits in a ice-marginal lake (Saalian, Leuvenumsche Beek Valley, Veluwe, The Netherlands), with emphasis on plugflow deposits. *Sediment. Geol.*, 34:59–82.

Sanders, J. E., 1965. Primary sedimentary structures formed by turbidity currents and related resedimentation mechanisms. *Soc. Econ. Paleontol. Miner., Spec. Publ.*, 12:192–219.

Schlager, W., Schlager, M., 1973. Clastic sediments associated with radiolarites (Tauglboden-Schichten, Upper Jurassic, Eastern Alps). *Sedimentology*, 20:65–89.

Shideler, G. L., Ślączka, A., Unrug, R. & Wendorff, M., 1975. Textural and mineralogical sorting relationships in Krosno Formation (Oligocene) turbidites, Polish Carpathian Mountains. *J. Sediment. Petrol.*, 45:44–56.

Stanley, D. J. & Unrug, R., 1972. Submarine channel deposits, fluxoturbidites and other indicators of slope and base-of-slope environments in modern and ancient marine basins. *Soc. Econ. Paleontol. Miner., Spec. Publ.*, 16:287–340.

Surlyk, F., 1984. Fan-delta to submarine fan conglomerates of the Volgian-Valanginian Wollaston Forland Group, east Greenland. In: E. H. Koster & R. J. Steel (eds.), *Sedimentology of gravels and conglomerates. Can. Soc. Petrol. Geol., Mem.*, 10:359–382.

Ślączka, A. & Thompson III, S., 1981. A revision on the fluxoturbidite concept based on type examples in the Polish Carpathian Flysch. *Ann. Soc. Geol. Pol.*, 51:3–44.

Unrug, R., 1963. Istebna-Beds – a fluxoturbidity formation in the Carpathian Flysch. *Ann. Soc. Geol. Pol.*, 33:49–92.

Walker, R. G., 1967. Turbidite sedimentary structures and their relationship to proximal and distal depositional environments. *J. Sediment. Petrol.*, 37:25–43.

Walker, R. G., 1970. Review of the geometry and facies organization of turbidites and turbidite-bearing beds. *Geol. Ass. Can., Spec. Pap.*, 7:219–251.

Walker, R. G., 1975. Generalized facies models for resedimented conglomerates of turbidite association. *Geol. Soc. Am. Bull.*, 86:737–748.

Walker, R. G. & Mutti, E., 1973. Turbidite facies and facies associations. In: Middleton, G. V. & Bouma, A. H. (eds.), *Turbidites and deep-water sedimentation. Soc. Econ. Paleontol. Miner., Pacific Section, Short Course Notes*, p. 119–157, Anaheim.

Wendorff, M., 1986. Facies relationships in the Krosno Beds in the eastern part of the Silesian tectonic unit: an outline of qualitative and quantitative analysis. In: *IAS 7th European Regional Meeting, Excursion Guidebook, Excursion No. B-7*, p. 121–125.

Winn, R. D. Jr. & Dott, R. H. Jr., 1979. Deep-water fan-channel conglomerates of late Cretaceous age, southern Chile. *Sedimentology*, 26:203–228.

Wood, A. & Smith, A. J., 1958. The sedimentation and sedimentary history of the Aberystwyth Grits (Upper Landdoverian). *Quart. J. Geol. Soc.*, 114:163–195.

Streszczenie

FLUKSOTURBIDYTY Z FLISZU POLSKICH KARPAT: ICH CECHY CHARAKTERYSTYCZNE, GENEZA ORAZ POZYCJA W AKTUALNYCH SCHEMATACH KLASYFIKACJI OSADÓW

Stanisław Leszczyński

Opracowanie stanowi próbę nowego spojrzenia na utwory określane mianem fluksoturbidytów. Wykonano je opierając się na analizie 164 ławic z kilku jednostek litostratygraficznych fliszu Karpat zewnętrznych (Fig. 1; Tab. 1).

Analizowane ławice zbudowane były z materiału od żwirowego po ilasty. Materiał żwirowy występuje w dolnej części ławic, ilasty i pyłowy natomiast koncentruje się w stropie ławic. Otoczaki ułożone są w ławicach chaotycznie lub wykazują ułożenie uporządkowane, najdłuższymi osiami i powierzchniami największego przekroju równolegle do siebie i do powierzchni uławicenia, nieraz są zimbrykowane (Fig. 2; Pl. IV: 1).

Fluksoturbidyty występują w ławicach prostych i złożonych (Pl. I: 2). W obrębie ławic złożonych wyróżniono ławice elementarne normalne i pseudoproste (Fig. 3; Pl. I: 2; Pl. II: 1). Średnia miąższość ławic prostych i pseudoprostych wynosi 2,7 m (Fig. 4). Miąższość ławic złożonych przekracza 1 metr i sięga kilkudziesięciu metrów. Powierzchnie ograniczające ławice proste i złożone są równe i płaskie, a także nierówne — erozyjne. Wewnątrz ławic zaznaczają się następujące struktury sedymentacyjne:

1) uziarnienie niefrakcjonalne (Pl. I: 2);
2) uziarnienie frakcjonalne normalne (Pl. II: 1; Pl. IV: 1);
3) uziarnienie frakcjonalne odwrócone (Pl. IV: 1);
4) pozioma laminacja drobnopiaszczysta (Pl. I: 2; Pl. II: 2; Pl. IV: 1; Fig. 5, 8);
5) wieloskalowe warstwowanie przekątne (Pl. III: 2; Fig. 8, 9, 10);
6) struktury ucieczkowe wody;
7) struktury sekwencji Boumy T_{b-e}.

Piaskowcową, zlepieńcowo-piaskowcową część ławicy, w której występują struktury 1—6, oznaczono symbolem F, natomiast część stropową ze strukturami sekwencji Boumy, oznaczono symbolem T. Członu T nie mają ławice elementarne normalne.

Częstość występowania poszczególnych rodzajów struktur jest różna (Tab. 2). Najczęściej występuje uziarnienie niefrakcjonalne oraz normalne uziarnienie frakcjonalne. W członie T najczęstsze są struktury T_{bd}. W związku z różną częstością występowania poszczególnych struktur, a zarazem z dość dużą różnorodnością teksturową fluksoturbidytów, również sekwencje tych cech w ławicach są znacznie zróżnicowane (Tab. 3 i 4; Fig. 5—14).

Wydzielono trzy rodzaje ławic fluksoturbidytowych różniące się składem granulometrycznym oraz sekwencją struktur:

1) ławice rozpoczynające się zlepieńcem tworzącym warstwę o miąższości powyżej 30 cm, stanowiącą ponad 20% miąższości całej ławicy, i zawierające otoczaki o średnicy powyżej 10 mm (oznaczone symbolem CS, Fig. 12);

2) ławice zdominowane piaskowcem z otoczakami, rozpoczynające się nieraz zlepieńcem tworzącym warstwę o miąższości do 30 cm, stanowiącą powyżej 20% miąższości całej ławicy, zawierające nieliczne otoczaki o średnicy powyżej 10 mm (oznaczone symbolem PS, Fig. 13);

3) ławice piaskowców bez otoczaków (oznaczone symbolem S, Fig. 14).

Na podstawie analizy sekwencji struktur oraz przejść poszczególnych struktur (Tab. 3, 4; Fig. 11) dla każdej grupy ławic określono ławicę idealną (Fig. 16A-C) i modalną (Fig. 16D-E). Ławica idealna przedstawia sekwencję zbiorczą wszystkich, zasadniczo różnych interwałów teksturowo-strukturowych stwierdzonych w ławicach grupy, którą reprezentuje. Ławica modalna przedstawia sekwencję występującą w grupie najczęściej. Ławica idealna grupy CS odpowiada w ogólności modelowi fluxoturbidytu według Ślączki i Thompsona (1981; Fig. 17A).

Analizowane fluxoturbidyty mieszczą się w facjach A i B Muttiego i Ricci Lucchiego (1972, 1975), Walkera i Muttiego (1973) oraz Pickeringa *et al.* (1986). Odpowiadają one zasadniczo osadom prądów zawiesinowych o wysokiej gęstości Lowe'a (1982), a podrzędnie również osadom bezkohezyjnych spływów rumoszowych oraz spływów materiału upłynnionego.

Ławice idealne fluxoturbidytów grupy CS (Fig. 16A) i PS (Fig. 16B) są podobne do modelowych ławic osadów prądów zawiesinowych o wysokiej gęstości, opisanych przez Lowe'a (1982). Ławica idealna grupy CS jest podobna do modelowej ławicy osadu żwirowego prądu zawiesinowego o wysokiej gęstości (Fig. 17C), a ławica idealna grupy PS (Fig. 16B) jest podobna pod względem zespołu struktur do ławicy modelowej osadu piaszczystego prądu zawiesinowego o wysokiej gęstości (Fig. 17B). Różni się od niej jednak sekwencją struktur. Ławica idealna grupy S odpowiada sekwencji Lowe'a S_3T, a także modelowej ławicy „klasycznego" turbidytu.

Cechy teksturowo-strukturowe fluxoturbidytów wskazują na depozycję tych utworów głównie z prądów zawiesinowych o wysokiej gęstości, rozumianych według koncepcji Lowe'a (1982). Zlepieńce oraz piaskowce o uziarnieniu niefrakcjonalnym mogły się osadzić tak z prądów zawiesinowych o wysokiej gęstości, jak i z innych rodzajów spływów: zlepieńce — ze spływów rumoszowych, piaskowce natomiast — ze spływów materiału upłynnionego.

Proste i pseudoproste ławice fluxoturbidytowe osadzały się w dwóch zasadniczo różnych etapach: 1) etap depozycji z zawiesiny o wysokiej gęstości; 2) etap depozycji z zawiesiny resztkowej, o niskiej gęstości. W etapie pierwszym osadzał się człon F, a w drugim człon T prostej lub pseudoprostej ławicy fluxoturbidytowej. Ławice elementarne normalne obejmują osad deponowany wyłącznie z zawiesiny o wysokiej gęstości.

Depozycja z zawiesiny o wysokiej gęstości odbywała się trzema zasadniczo różnymi sposobami (por. Lowe, 1982; Tab. 7):

1) poprzez masowe osiadanie zawiesiny (MS);

2) poprzez odcinanie od spływu i zamrażanie warstwy ładunku przydennego (SO);

3) poprzez osiadanie pojedynczymi cząstkami, wleczonymi przed depozycją po dnie (z trakcji, TS).

Głównym sposobem depozycji fluksoturbidytów było masowe osiadanie zawiesiny (Tab. 7). W efekcie takiej depozycji powstał osad nielaminowany (F2, F4, F6 oraz F1+F2). Depozycja typu SO znaczy się osadem z poziomymi laminami drobnopiaszczystymi (F5), depozycja typu TS natomiast jest reprezentowana zestawami warstwowanymi przekątnie w dużej skali, z warstwowaniem podkreślonym ułożeniem otoczaków. Depozycja z resztkowej zawiesiny rozrzedzonej odgrywała znikomą rolę w formowaniu ławic fluksoturbidytowych. W jej efekcie powstawały interwały T_{bcd}.

Złożone ławice fluksoturbidytowe są po części efektem depozycji z wielopulsowych prądów zawiesinowych o wysokiej gęstości, po części zaś efektem amalgamacji ławic osadzonych z oddzielnych spływów.

Sedymentacja analizowanych ławic różniła się od opisanej w modelu Lowe'a (1982) mniejszym zróżnicowaniem sposobów depozycji. Osadziły się one z prądów szybko hamujących. Cechy analizowanych fluxoturbidytów wskazują na osadzanie się ich w basenach o nierównej morfologii dna, a także (lub) otoczonych niezbyt wysokimi albo też niezbyt stromymi zboczami, a ponadto o dnie mobilnym.

Niezależnie od modeli wskazanych dla analizowanych fluxoturbidytów (ławice idealne) za modele takich utworów można również uznać modele osadów prądów zawiesinowych o wysokiej gęstości określone przez Lowe'a (1982). Do modeli osadów prądów zawiesinowych o wysokiej gęstości proponuje się włączyć model ławic zbudowanych z materiału piaszczystego i drobniej ziarnistego. Model taki w niniejszej pracy reprezentuje ławica idealna fluxoturbidytów grupy S, różniąca się ogólnie od modelu turbidytu podrzędną miąższością sekwencji T_{b-e} w stosunku do interwału piaskowca o charakterze T_a.

EXPLANATION OF PLATES

All photos taken in eposures of the Ciężkowice Sandstone, Palaeocene

Plate I

1 — Fragment of composite bed (top to the left). Amalgamation surface (dotted) is deformed by loading. Lower, elementary bed shows from base upwards: dish structures in sandstone (arrowed), flat lamination (T_b), and homogeneous sandstone. Upper bed begins with normally graded pebbly sandstone. Ostrusza near Ciężkowice. Hammer is 35 cm long

2 — Composite fluxoturbidite beds (top to the left). Lower, pseudosimple bed shows from base upwards: conglomeratic division horizontal fine-sand laminae, homogeneous sandstone, and flat

laminated sandstone (T_b). Upper, composite bed consists of two elementary beds separated by amalgamation surface (dotted). Warownia Tor at the Skamieniałe Miasto protected site, near Ciężkowice. Ruler is 20 cm long

Plate II

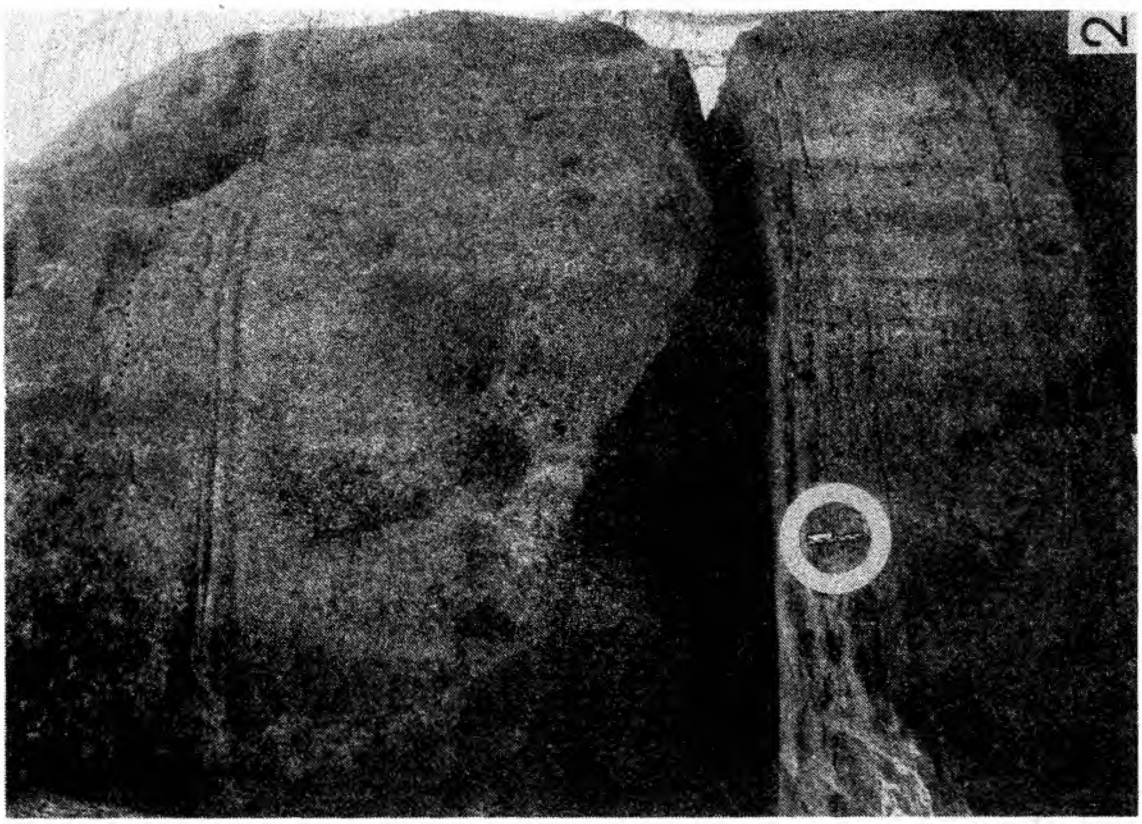
1 – Fragment of composite fluxoturbidite bed consisting of four elementary beds showing normally graded conglomerate and sandstone divisions and horizontal fine-sand laminae in upper parts of two lower beds. These two beds were probably deposited from separate pulses of single flow. Quarry at Łęki Strzyżowskie
2 – Fragment of composite bed consisting of two beds separated by sharp, uneven boundary. Basal part of upper bed exhibits microconglomerate lenses, overlain by pebbly sandstone (with horizontal fine-sand lamination). Vicinity of Odrzykoń Castle

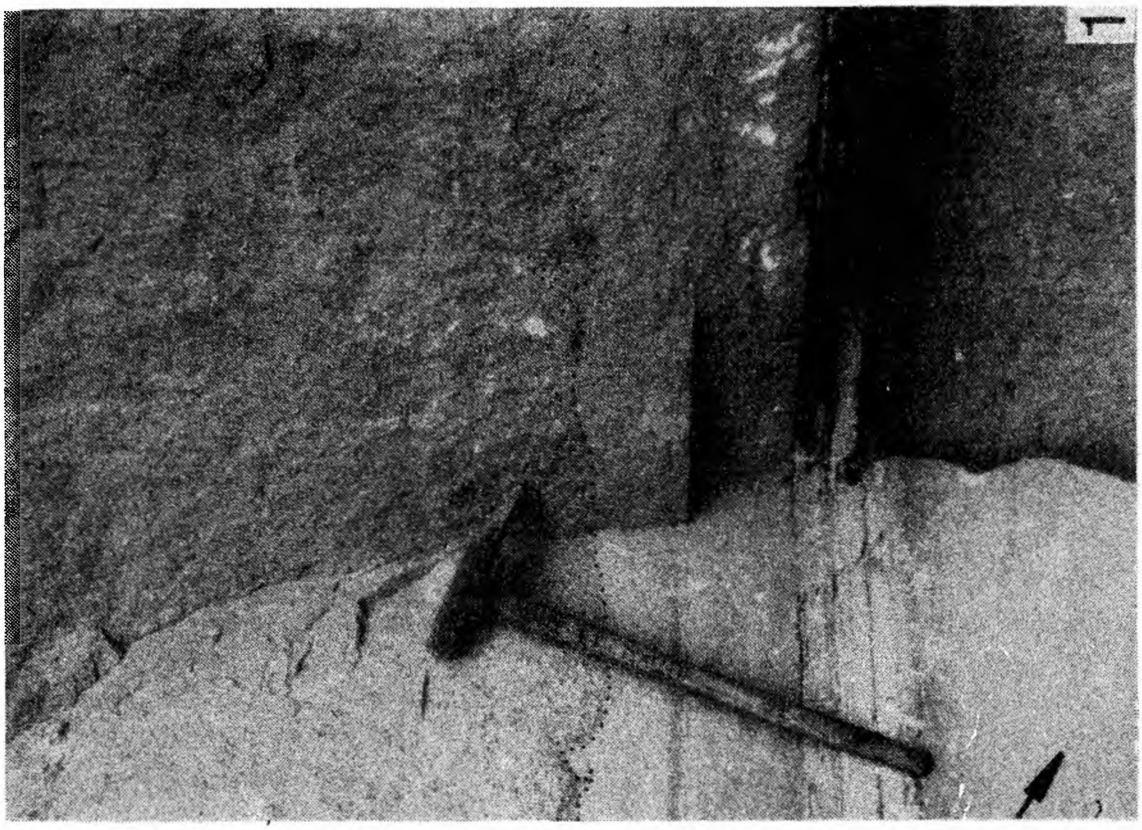
Plate III

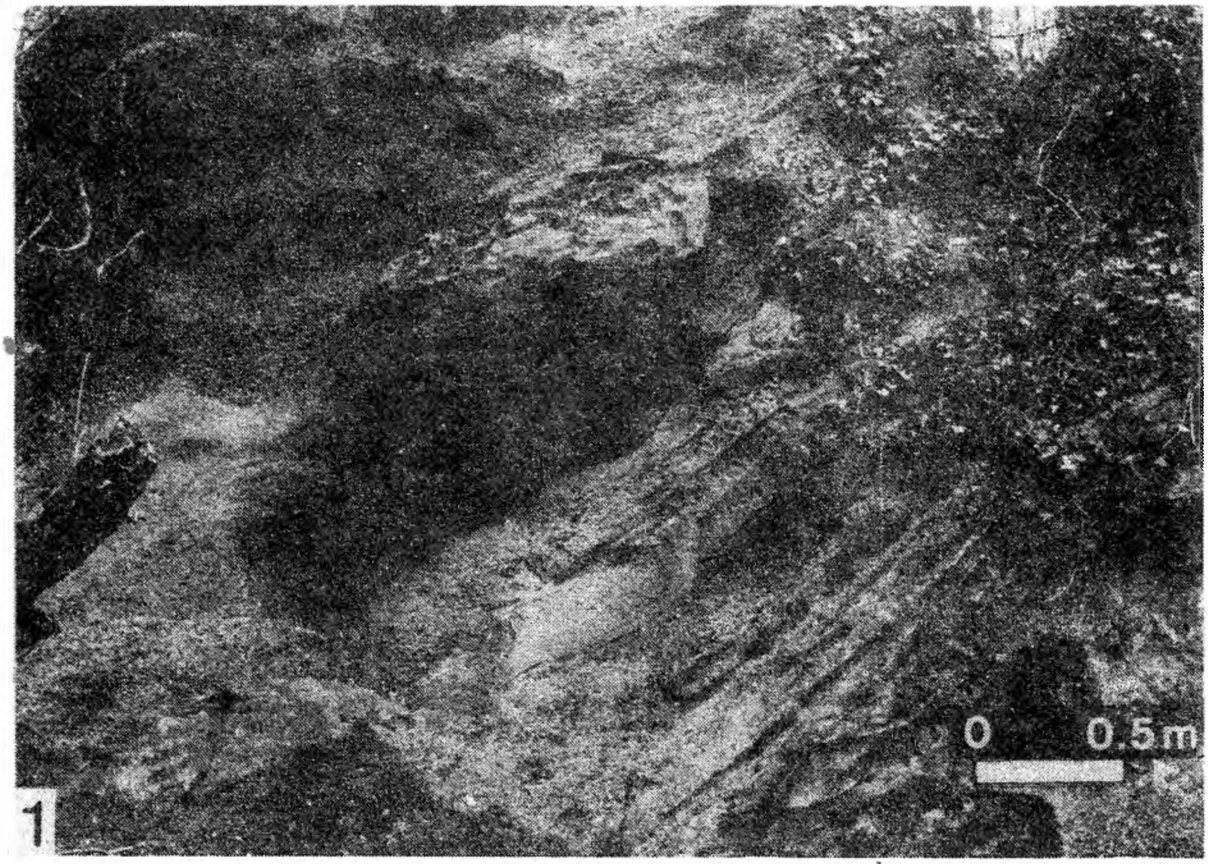
1 – Fragment of fluxoturbidite bed showing horizontal fine-sand laminated division. Well-developed inverse grading occur within some coarse laminae. Warownia Tor in the Skamieniałe Miasto protected site, near Ciężkowice. Ruler is 10 cm long
2 – Lower part of elementary pebbly sandstone bed, showing trough cross-stratification (1) dying out laterally and upwards within ungraded pebbly sandstone. Arrow indicates base of bed. NE of Krosno. Ruler is 10 cm long

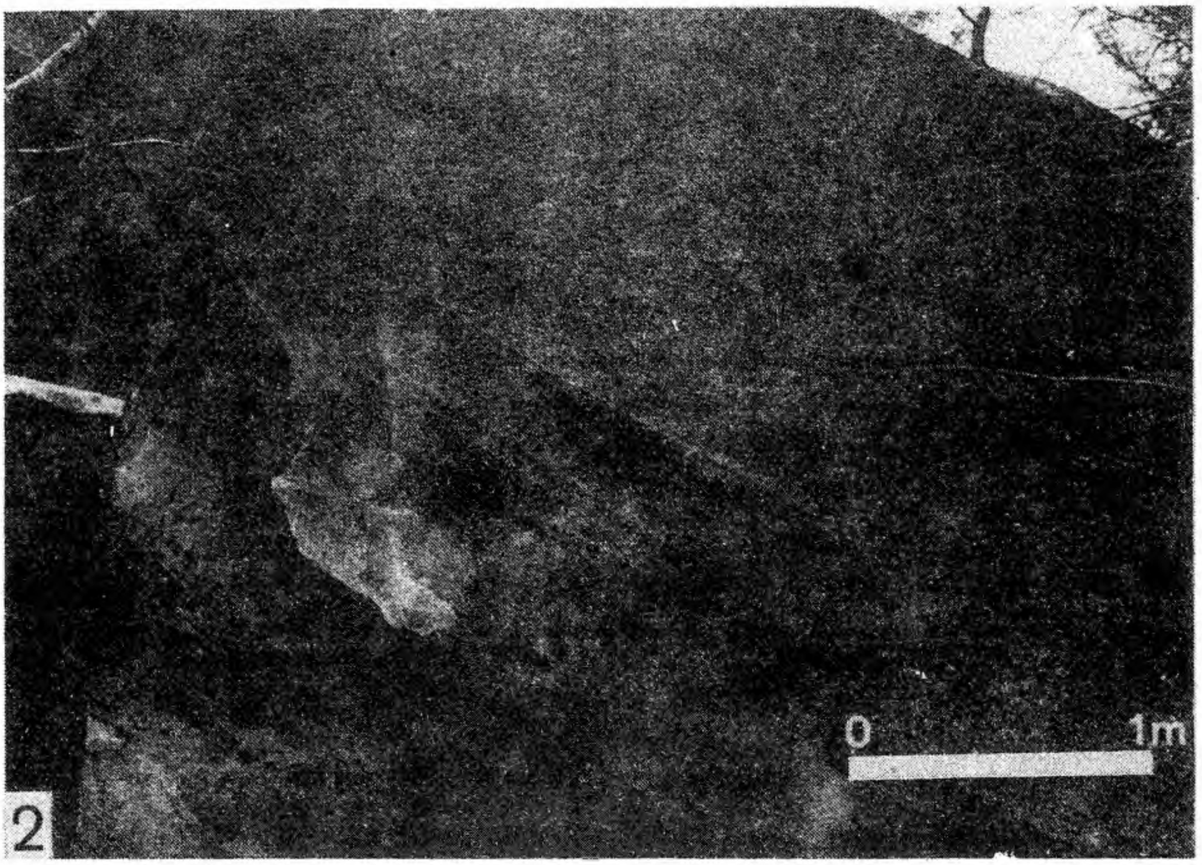
Plate IV

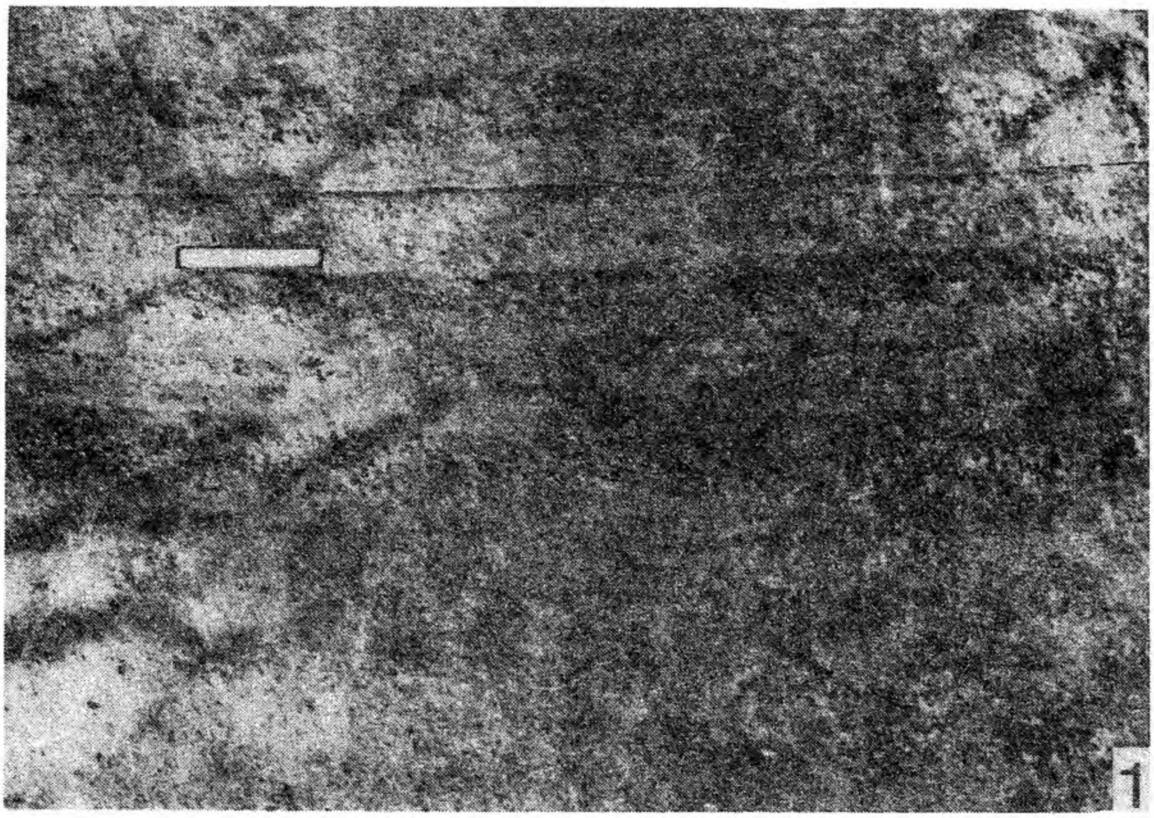
1 – Fragment of composite fluxoturbidite bed, showing well-developed imbrication of elongated clasts and inverse to normal grading in conglomerate which passes downwards and upwards into sandstone. This bed was probably deposited from surging flow. Quarry in Łęki Strzyżowskie. Ruler is 20 cm long
2 – Fragment of composite bed showing two elementary beds amalgamated along uneven, erosional surface. Lower bed shows normally graded division passing upwards into horizontal fine-sand laminae. Upper bed commences with normally graded microconglomerate. Vicinity of Odrzykoń Castle

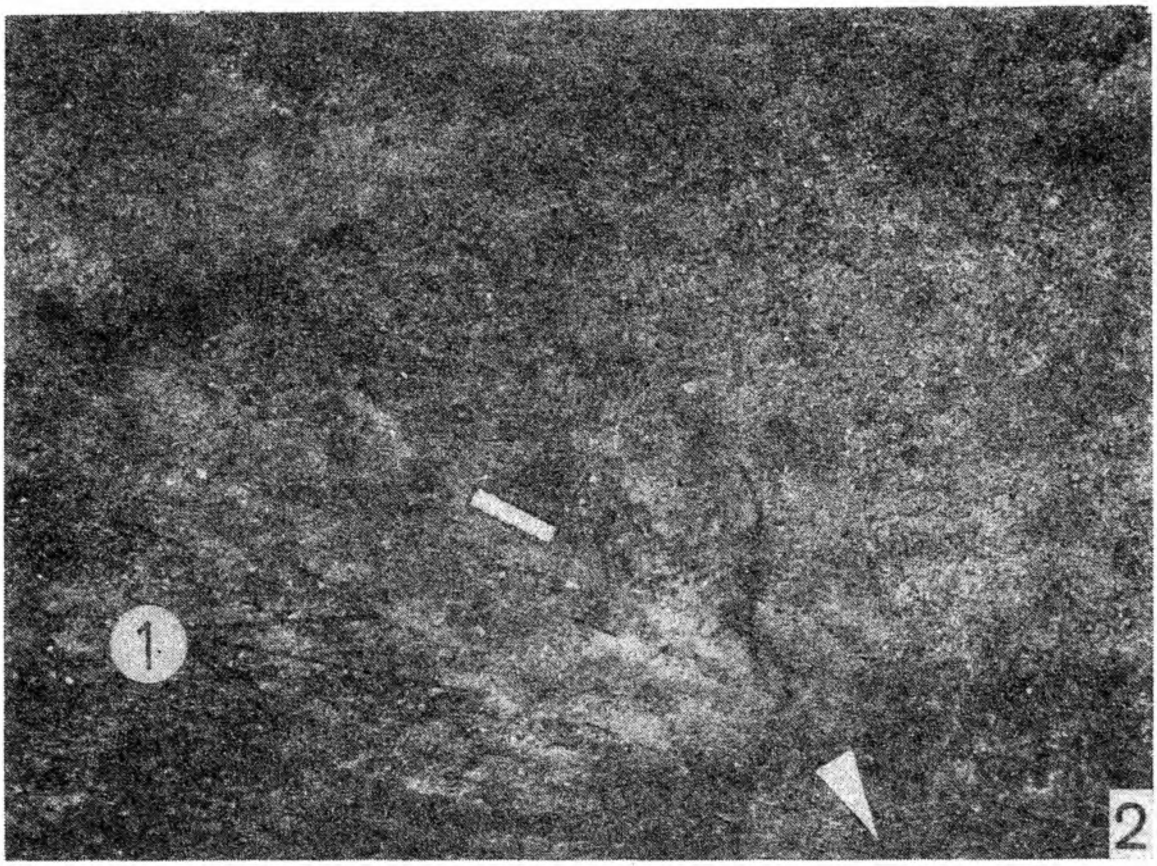

2

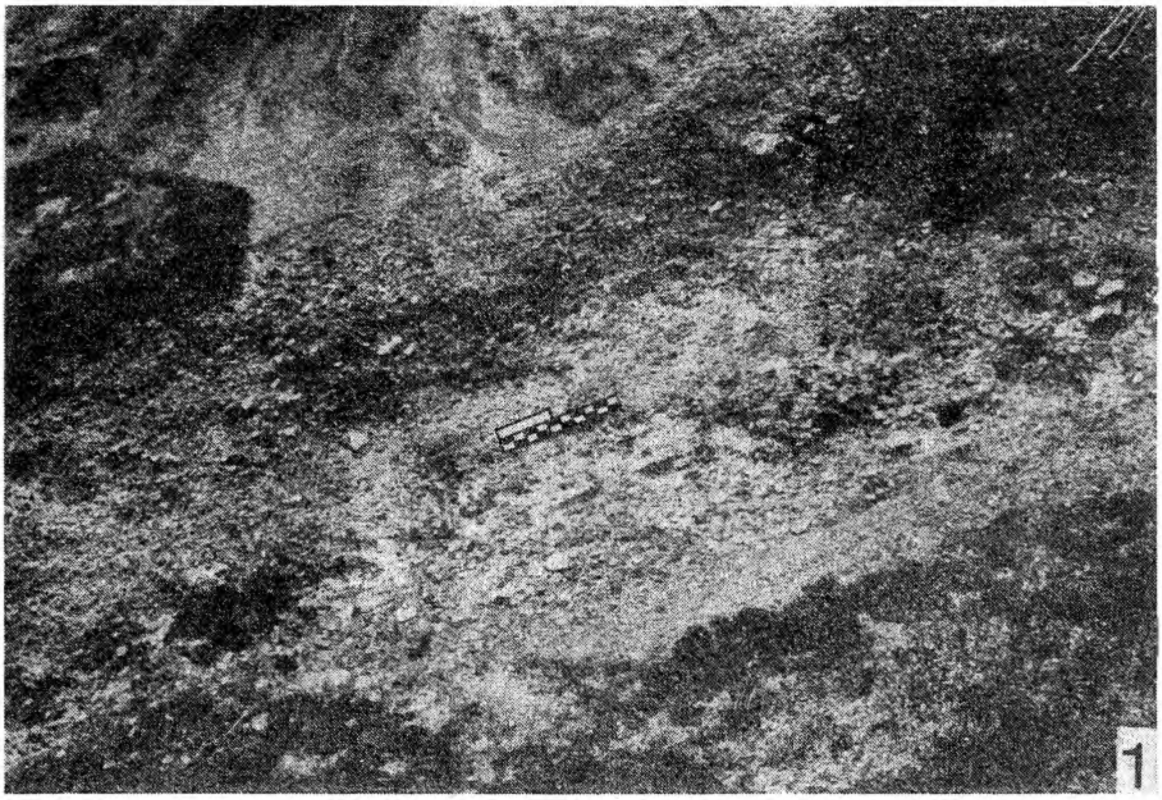

1


1
0 0.5m


2
0 1m


1


1
2


1


2