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Interpretation of Depositional Environment Based on Grain Size Distribution of Sandstones of the Val Gardena Formation in the Area Between Cerkno and Smrečje, Slovenia

Interpretacija sedimentacijskega okolja na osnovi porazdelitve velikosti zrn peščenjakov grödenske formacije na območju med Cerknim in Smrečjem, Slovenija

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Ključne besede: velikosti zrn, sedimentacijsko okoje, peščenjaki, grödenska formacija, perm, Slovenija

Abstract

An attempt was made to interpret the mode of transport and the depositional environment of sandstones of the Val Gardena Formation in the area between Cerkno and Smrečje by analysis of frequency distribution of lengths of long axes of sections of quartz grains. The examined sandy fraction should have been transported by fluvial currents principally in the saltation and partly the suspension population, and in a smaller degree in the rolling population of grains.

Kratka vsebina

Z analizo porazdelitve dolgih osi presekov kremenovih zrn peščenjakov grödenske formacije na območju med Cerknim in Smrečjem smo skušali podati interpretacijo načina transporta in sedimentacijskega okolja. Analizirana peščena frakcija naj bi bila transportirana z rečnimi tokovi pretežno v obliki poskakujoče, deloma suspenzijske in v manjši meri kotaleče populacije zrn.

Introduction

The largest continuous belt of the clastic rocks of the Val Gardena Formation in Slovenia extends in the area between Cerkno and Smrečje where they take part of the Žiri-Idrija nappe unit (Mlakar, 1969). According to the twofold subdivision of the Permian they are attributed to the lower part of the Upper Permian. The beds underlying the Val Gardena Formation consist of dark grey clastic rocks of presumingly Carboniferous age, while their upper part might be of the Lower Permian age. The contact with them is discordant. The passage into overlying beds of the Upper Permian carbonate rocks is gradual and concordant.

The most frequent rocks of the Val Gardena Formation are developed in the red sandstone facies, in which conglomeratic and muddy facies are interbedded. As a consequence of their proportion the highest attention in the study of the Val Gardena Formation was attributed to the sandstones.

A sandstone as a clastic sedimentary rock consists of terrigenous grains and of chemically precipitated minerals. Its properties depend therefore upon the properties of grains and their fabric. The characteristics of an aggregate of sediment grains (P) can consequently be defined as a function of their composition (c), size (s), shape (sh), and their fabric, described by orientation (o) and packing (p) (Griffiths, 1961, 1967).

$$P = f(c, s, sh, o, p)$$

Determination of one of the given parameters is usually interdependent upon the others. The basic properties of solid cemented rocks that cannot be disintegrated into primary particular grains without the influence on their primary size and shape, can be determined only in thin sections. In this case, an additional variable, the direction of the section across the grain aggregate of the rock must be considered.

In the following, only the size, or distribution of sizes, of terrigenous grains in the considered rocks shall be dealt with.

The grain sizes in sandstones that can be disintegrated into their primary individual grains is usually determined by sieving. During disintegration the original fabric of grains, that is their orientation (o) and packing (p), is destroyed. From this aspect, the determination of grain size (P_s) depends only upon the composition (c), size (s) and shape (sh) of grains.

$$P_s = f(c, s, sh)$$

Owing to the importance of grain size, or of its distribution in sandstones from the technological, as well as from genetic aspects, various authors (Friedman, 1958, 1962; Adams, 1977; Harrell & Erikson, 1976; Johnson, 1994) attempted to determine the correction factors for transformation of the lengths of long axes of grain sections in thin sections into the grain sizes as determined by sieving. One comes across the problems of the definition of grain size that is dependent upon the method applied (Allen, 1968) and the determination of the "true" size in thin sections, which also represents a mathematical problem. Analysis of the mentioned problems are beyond our frame. Lately they were discussed by Johnson (1994).

For a long time in sedimentary petrology, many attempts were made to use the grain size of the sediment for determination of their depositional environment.

Grain size distribution in clastic sedimentary rocks is dependent upon the characteristics of source rocks, mode of weathering, distribution of grain size in weathered material, mode of transport, conditions of sedimentation and finally of postdepositional processes. An interpretation of the depositional environment by grain size distributions is based upon the assumption that they are predominantly affected by hydrodynamic properties of the currents during transport and sedimentation, which would be typical for the distinct depositional environment. The latter represents the most difficult problem, since equal or very similar depositional processes and corresponding hydrodynamic conditions may occur in various depositional environments, and thus affect the grain size distributions in a similar manner. Therefore the studies of grain size distributions are only in part successful in determining the paleodepositional environments and the depositional processes related with them.

In spite of the stated limitations an attempt was made to use the distribution of lengths of long axes of sections of terrigenous quartz grains of the sandy fraction for interpretation of the mode of transport and of the depositional environment of the Val Gardena sandstones in the Cerkno-Smrečje area.

Sampling and methodology

In total 209 point samples have been analyzed in detail from 18 local profiles-segments (OZS), which all together comprise a thickness of 1234 m. The local profiles-segments can be assembled into five regional composite profiles (OZP): Škofje, Sovodenj, Žirovski vrh, Goli vrh and Lavrovec, as arranged in the direction from NW to SE. They represent the fairly well studied volume of the Val Gardena Formation.

The long axes of 200 sections of quartz grains were measured with the micrometer ocular at 150 × magnification in 206 thin sections. The measured quartz grains were randomly selected by point counter. The influence of composition on size determination was reduced by measuring the quartz grains only. They are also the principal component in the composition of the Val Gardena sandstones and represent on average 63 % of the population of all terrigenous grains. The lengths of long axes, up to 5 Φ (0.03 mm), were subdivided into classes of 1/4 Φ wide, and below that into classes of 1/2 Φ wied, down to the smallest measured size of about 7 Φ (0.008 mm). The relative and cumulative frequencies were calculated on the basis of these data for the use in further analysis.

Results

The cumulative frequency distribution curves of the lengths of long axes of sections of quartz grains were drawn in the Φ units on the abscissa and the probability scale on the ordinate. By using the cumulative frequency distribution curves the graphic statistical parameters: graphic mean size (MZ), inclusive standard deviation (SI), inclusive graphic skewness (SKI) and graphic kurtosis (KG) (Folk & Ward, 1957) were determinated. From the same curves also the metric sizes at 1 % (C) and median (MD), as well as quartile deviation (QDa) (Buller & Mc Manus, 1972) were also obtained. The average size (M), standard deviation (S), skewness (SKEW), kurtosis (KURT), simple measure of skewness (ALFA) and mean cubic deviation (MCD) (Friedman, 1967) were also calculated with the moment estimates. They were calculated in spite of difficulties related with the partly open classes in the domains of the smallest and the largest grain sizes, as warned by Folk (1966). The mentioned parameters for individual analyzed samples are listed in table 1, and the descriptive statistics of grain size data are summarized in table 2.

Table 1. Granulometric parameters

CASE NAME	OZP	OZS	M	S	SKEW	KURT	ALFA	MZ
P10/8/400	ZIROV. V.	P10	2.08	.808	.409	3.164	.216	2.03
P10/8/200	ZIROV. V.	P10	2.20	.904	.697	3.669	.514	2.13
P10/9/120	ZIROV. V.	P10	2.41	.643	.320	2.424	.085	2.40
P10/9/300	ZIROV. V.	P10	2.49	.786	.158	2.884	.077	2.50
P10/16/500	ZIROV. V.	P10	2.93	.723	.589	3.886	.222	2.93
P10/16/130	ZIROV. V.	P10	3.19	.781	.838	3.511	.399	3.15
P10/25/500	ZIROV. V.	P10	1.96	.574	.035	2.694	.007	1.95
P10/25/175	ZIROV. V.	P10	2.73	.739	.661	3.740	.267	2.67
P10/34/100	ZIROV. V.	P10	1.98	.680	.556	4.271	.175	2.00
P10/34/300	ZIROV. V.	P10	2.50	.580	.691	3.355	.135	2.50
P10/35/800	ZIROV. V.	P10	1.84	.592	.093	2.764	.019	1.85
P10/40/100	ZIROV. V.	P10	1.89	.585	.136	2.461	.027	1.90
P10/40/250	ZIROV. V.	P10	2.33	.641	-.197	3.151	-.052	2.35
P10/53/500	ZIROV. V.	P10	1.82	.656	-.529	3.073	-.149	1.85
P10/53/150	ZIROV. V.	P10	3.45	.803	.874	3.321	.452	3.12
P10/57/100	ZIROV. V.	P10	2.54	.785	.610	4.663	.295	2.25
P10/57/700	ZIROV. V.	P10	4.32	.769	.261	1.893	.118	3.95
P10/76/120	ZIROV. V.	P10	1.77	.782	.097	2.808	.046	1.50
P10/76/220	ZIROV. V.	P10	1.08	.627	-.230	2.541	-.057	.85
P10/78/500	ZIROV. V.	P10	.90	.593	-.048	2.591	-.010	.88
P10/78/130	ZIROV. V.	P10	1.07	.614	-.108	3.087	-.025	1.13
P10/81/220	ZIROV. V.	P10	1.04	.606	.155	2.749	.034	1.05
P10/81/320	ZIROV. V.	P10	1.60	.730	.190	2.570	.074	1.60
H53/1	ZIROV. V.	H53-54	.81	.598	.206	2.581	.044	.83
H53/6	ZIROV. V.	H53-54	2.35	.660	.117	2.550	.034	2.37
H54/246	ZIROV. V.	H53-54	1.26	.613	.261	3.103	.060	1.27
H54/2	ZIROV. V.	H53-54	1.20	.608	-.131	2.669	-.029	1.22
H54/10	ZIROV. V.	H53-54	.79	.646	-.189	2.711	-.051	.80
H54/11	ZIROV. V.	H53-54	.82	.645	.113	2.915	.030	.85
H54/21	ZIROV. V.	H53-54	1.91	.634	.277	2.804	.071	1.90
H54/23	ZIROV. V.	H53-54	1.07	.617	.073	2.782	.017	1.05
H54/31	ZIROV. V.	H53-54	.98	.613	-.224	3.354	-.052	1.02
H54/33	ZIROV. V.	H53-54	1.51	.705	.190	2.583	.066	1.52
H54/35	ZIROV. V.	H53-54	1.20	.699	.317	2.916	.108	2.18
H54/222	ZIROV. V.	H53-54	1.38	.788	.401	2.907	.196	1.38
H54/48	ZIROV. V.	H53-54	1.17	.789	.157	2.503	.077	1.17
H54/60	ZIROV. V.	H53-54	1.88	.596	-.169	2.905	-.036	1.90
H54/202	ZIROV. V.	H53-54	1.62	.777	.300	3.010	.141	1.63
H54/160	ZIROV. V.	H53-54	2.43	.765	.353	2.513	.158	2.42
H54/66	ZIROV. V.	H53-54	1.79	.726	.110	2.547	.042	1.80
H54/71	ZIROV. V.	H53-54	1.52	.665	.013	2.656	.004	1.50
H54/72	ZIROV. V.	H53-54	1.88	.654	.406	3.019	.113	1.90
H52/401	ZIROV. V.	H52	.96	.627	.105	3.399	.026	.97
H52/402	ZIROV. V.	H52	1.11	.611	.125	3.186	.029	1.10
H52/404	ZIROV. V.	H52	1.50	.608	.276	2.678	.062	1.48
H52/407	ZIROV. V.	H52	2.05	.758	.377	2.805	.164	2.05
H52/465	ZIROV. V.	H52	1.71	.727	.245	3.256	.094	1.70
H52/427	ZIROV. V.	H52	1.75	.769	.486	3.126	.221	1.75
H52/429	ZIROV. V.	H52	2.65	.782	.702	3.782	.336	2.63
H52/431	ZIROV. V.	H52	1.78	.704	.845	3.862	.295	1.73
H52/493	ZIROV. V.	H52	1.67	.901	.153	2.441	.112	1.68
H52/495	ZIROV. V.	H52	1.73	.672	.176	2.936	.053	1.75
K1/7.2	ZIROV. V.	KL	2.33	.607	.035	2.792	.008	2.33
K1/7.2/1	ZIROV. V.	KL	2.51	.580	.346	3.198	.068	2.50
K1/13.1	ZIROV. V.	KL	1.37	.630	.552	2.941	.138	1.37
K1/20.3	ZIROV. V.	KL	1.84	.700	.071	2.648	.024	1.85
K1/28.0	ZIROV. V.	KL	2.50	.648	.038	3.207	.010	2.50
K1/32.7	ZIROV. V.	KL	1.47	.772	.854	3.579	.393	1.40
K1/37.7	ZIROV. V.	KL	2.28	.654	.200	4.267	.056	2.30
K1/46.3	ZIROV. V.	KL	1.61	.792	1.092	4.834	.543	1.53
K1/51.0	ZIROV. V.	KL	1.96	.660	.689	4.287	.198	1.93
K1/51.0/1	ZIROV. V.	KL	2.02	.771	1.013	5.171	.465	1.98
K1/54.7	ZIROV. V.	KL	2.55	.786	.645	3.790	.313	2.55
K1/71.0	ZIROV. V.	KL	1.37	.820	.925	3.859	.510	1.25
K1/76.8	ZIROV. V.	KL	2.28	.679	.368	3.523	.115	2.27
K1/79.3	ZIROV. V.	KL	2.60	.742	.336	3.384	.137	2.62
K1/83.9	ZIROV. V.	KL	1.83	.739	.483	3.259	.195	1.82
K1/84.9	ZIROV. V.	KL	1.87	.611	.509	3.094	.116	1.87
K1/88.9	ZIROV. V.	KL	2.75	.632	.425	3.508	.107	2.70
Ra1/0.7	ZIROV. V.	RA1	2.31	.785	.218	3.444	.105	2.53
Ra1/2.4	ZIROV. V.	RA1	1.16	.537	.765	4.077	.119	1.25
Ra1/4.75	ZIROV. V.	RA1	.96	.624	.856	2.783	.207	.85

Tabela 1. Granulometrični parametri

SI	SKI	KG	C	MD	QDa	MCD	Ro	Sa	Su	ϕSu	BL%
.784	-.098	1.165	.707	.233	.085	.216	0	2	1	2.70	77
.872	.123	1.151	.707	.250	.082	.515	0	1	1	2.60	77
.671	.124	1.066	.500	.196	.058	.085	0	1	1	2.40	54
.794	0.000	1.066	.500	.177	.063	.077	0	1	0		100
.643	.124	.956	.354	.134	.041	.223	0	1	0		100
.714	.253	1.093	.297	.121	.036	.399	0	1	1	3.20	58
.563	0.000	1.038	.660	.259	.067	.007	0	1	0		100
.709	.110	1.038	.392	.159	.052	.267	0	2	1	3.30	84
.611	-.012	1.050	.707	.250	.070	.175	0	1	1	3.00	95
.575	.170	1.038	.379	.183	.047	.135	0	2	1	3.20	90
.588	0.000	.973	.707	.277	.078	.019	0	1	0		100
.580	.041	.948	.707	.268	.075	.027	0	2	0		100
.449	-.065	.589	.683	.196	.055	-.052	0	-2	1	2.90	84
.646	-.151	1.127	1.000	.268	.078	-.149	0	-2	0		100
.683	.185	.949	.250	.121	.038	.453	0	2	0		100
.704	-.253	1.138	.707	.210	.067	.295	1	1	1	3.00	87
.706	.203	1.014	.177	.069	.022	.119	0	1	1	4.00	62
.729	.020	1.025	1.320	.354	.125	.046	0	1	1	2.30	87
.658	0.000	1.002	1.866	.555	.176	-.057	1	0	0		100
.603	.092	1.025	1.414	.555	.150	-.010	0	1	0		100
.618	.065	1.013	1.320	.467	.142	-.025	0	2	0		100
.641	.108	.964	1.189	.500	.147	.034	0	2	0		100
.723	.022	.943	.901	.330	.117	.074	0	2	0		100
.616	.065	.964	1.320	.574	.169	.044	0	2	0		100
.671	.041	1.000	.500	.196	.062	.034	0	2	0		100
.591	.047	1.025	1.000	.420	.118	.060	0	1	1	2.00	90
.623	.032	.988	1.189	.435	.128	-.029	0	1	0		100
.651	-.012	.979	1.741	.574	.182	-.051	0	-2	0		100
.638	.118	1.101	1.516	.574	.161	.030	0	2	0		100
.893	.045	1.013	.758	.268	.081	.071	0	-2	1	2.40	80
.611	.012	1.050	1.275	.483	.136	.017	0	2	0		100
.583	.090	1.066	1.682	.500	.129	-.052	1	1	0		100
.698	.115	.992	.933	.366	.116	.067	0	2	0		100
.691	.181	.971	.595	.225	.074	.108	0	2	1	3.40	96
.786	.096	.950	1.516	.392	.153	.196	1	2	1	1.80	70
.556	.034	.969	1.320	.451	.176	.077	0	2	0		100
.595	-.013	.999	.758	.268	.075	-.036	0	2	0		100
.784	.099	1.107	1.189	.330	.117	.141	0	-2	1	2.00	73
.809	.221	1.107	.500	.196	.067	.158	0	2	1	2.70	73
.723	0.000	.943	.785	.287	.102	.042	0	2	1	3.00	96
.683	0.000	1.002	.933	.354	.112	.004	0	2	0		100
.573	.165	.988	.707	.277	.081	.114	0	2	0		100
.591	.047	1.025	1.569	.518	.145	.026	1	2	0		100
.611	.012	1.050	1.231	.467	.131	.029	0	1	1	2.00	93
.578	.117	1.025	.841	.366	.099	.062	0	2	0		100
.766	.108	1.014	.732	.250	.087	.164	0	2	0		100
.714	.021	1.035	.933	.308	.101	.094	0	1	1	2.65	93
.741	.112	1.079	.901	.308	.101	.221	0	2	0		100
.731	.108	.917	.420	.165	.060	.336	0	2	1	4.00	96
.689	.163	1.230	.707	.308	.086	.295	0	2	1	2.50	80
.927	.004	.951	1.110	.308	.152	.112	0	2	0		100
.651	.050	1.025	.901	.297	.094	.053	0	1	1	3.00	97
.616	-.020	.964	.500	.196	.060	.008	0	2	0		100
.568	0.000	1.038	.451	.177	.046	.068	0	1	0		100
.638	.078	1.175	1.000	.392	.105	.138	0	2	0		100
.706	-.011	.963	.966	.277	.098	.024	0	-2	0		100
.623	-.096	1.050	.500	.171	.050	.010	0	-2	0		100
.779	.152	1.252	1.110	.392	.124	.393	0	-2	0		100
.593	0.000	1.148	.637	.203	.054	.056	0	-2	1	2.80	92
.722	.073	1.302	.966	.342	.104	.542	0	1	1	2.00	88
.611	.103	1.120	.683	.268	.069	.198	0	2	1	3.20	98
.694	.188	1.070	.683	.268	.082	.464	0	2	1	3.00	95
.706	-.011	1.014	.555	.171	.058	.313	0	1	1	3.50	95
.887	.041	1.042	1.682	.420	.180	.510	0	1	1	2.00	88
.656	-.116	.956	.500	.196	.067	.115	0	1	1	2.90	92
.706	.125	1.070	.555	.171	.052	.137	0	1	0		100
.706	.146	.963	.812	.297	.098	.195	0	2	0		100
.568	.301	.907	.637	.297	.081	.116	0	2	0		100
.563	0.000	1.112	.392	.154	.038	.107	0	1	0		100
.721	-.757	1.057	.555	.165	.058	.105	0	-2	0	3.40	94
.478	-.160	1.391	1.072	.406	.042	.118	0	2	0		100
.802	-.009	.987	2.071	.555	.224	.208	0	2	0		100

CASE NAME	OZP	OZS	M	S	SKEW	KURT	ALFA	MZ
Ra1/6.0	ZIROV. V.	RA1	1.64	.602	.636	3.436	.139	1.65
Ra1/7.25	ZIROV. V.	RA1	1.75	.729	1.039	6.315	.403	1.73
Ra1/8.0	ZIROV. V.	RA1	.75	.448	1.255	4.184	.113	.55
B74/465.2	GOLI V.	B74	1.88	.640	.471	3.718	.123	1.85
B74/452.15	GOLI V.	B74	2.29	.920	.545	3.037	.423	2.23
B74/445.05	GOLI V.	B74	1.33	.542	.746	4.574	.119	1.30
B74/424.8	GOLI V.	B74	1.77	.633	.011	2.781	.003	1.75
B74/406.8	GOLI V.	B74	2.53	.587	.776	4.369	.157	2.52
B74/399.0	GOLI V.	B74	1.51	.610	.193	2.770	.044	1.50
B74/379.4	GOLI V.	B74	1.69	.651	-.054	3.104	-.015	1.70
B74/328.9	GOLI V.	B74	2.45	.652	.145	3.145	.040	2.45
B74/319.7	GOLI V.	B74	2.98	.635	.658	3.852	.168	2.95
B74/311.3	GOLI V.	B74	2.12	.639	.368	3.613	.096	2.10
B74/307.7	GOLI V.	B74	1.86	.537	.130	2.470	.020	1.88
B74/279.2	GOLI V.	B74	2.97	.638	.638	3.241	.166	2.87
B74/259.3	GOLI V.	B74	2.39	.567	.349	3.127	.063	2.38
B74/228.5	GOLI V.	B74	3.53	.686	.779	3.388	.252	3.52
B74/168.0	GOLI V.	B74	2.87	.515	.117	3.305	.016	2.87
B74/146.4	GOLI V.	B74	2.64	.829	.916	3.873	.522	2.58
B74/121.4	GOLI V.	B74	2.71	.660	.824	4.363	.237	2.68
B74/102.5	GOLI V.	B74	1.78	.719	.158	3.131	.059	1.78
B74/83.0	GOLI V.	B74	2.42	.639	.423	3.313	.110	2.40
B74/53.1	GOLI V.	B74	2.64	.779	.721	4.109	.341	2.67
B74/31.8	GOLI V.	B74	2.41	.666	.509	3.094	.151	2.42
B74/22.2	GOLI V.	B74	2.46	.701	.645	3.246	.222	2.43
Gv/7.3	LAVROVEC	GV	3.25	.747	.789	3.740	.329	3.15
Gv/10.0	LAVROVEC	GV	2.50	.667	.197	2.945	.059	2.50
Gv/25.3	LAVROVEC	GV	2.78	.676	.196	3.236	.060	2.70
Gv/33.3	LAVROVEC	GV	2.18	.563	.323	3.576	.058	2.15
Gv/39.0	LAVROVEC	GV	2.65	.541	.340	3.240	.054	2.65
Ra2/1.3	GOLI V.	RA2	2.22	.549	.612	3.757	.101	2.20
Ra2/2.3	GOLI V.	RA2	2.27	.565	.526	3.693	.095	2.27
Ra2/3.6	GOLI V.	RA2	2.07	.596	.072	3.360	.015	2.07
Ra2/5.2	GOLI V.	RA2	1.30	.578	.402	2.665	.078	1.27
Ra2/6.0	GOLI V.	RA2	2.35	.583	.369	3.296	.073	2.35
Ra2/8.5	GOLI V.	RA2	1.62	.530	.434	3.525	.064	1.62
Ra2/10.7	GOLI V.	RA2	1.86	.641	.285	2.667	.075	1.85
Ra3/3.6	LAVROVEC	RA3	1.26	.618	.496	3.019	.117	1.30
Ra3/5.1	LAVROVEC	RA3	1.46	.665	.263	2.505	.077	1.50
Pr/8.5	LAVROVEC	PR	2.13	.622	.382	3.323	.092	2.13
Pr/12.2	LAVROVEC	PR	2.31	.640	.403	3.549	.106	2.32
Pr/23.3	LAVROVEC	PR	2.45	.677	.197	3.399	.061	2.48
Pr/26.0	LAVROVEC	PR	1.82	.746	.432	2.913	.179	1.85
A/0.8	SOVODENJ	A	1.83	.900	-.140	3.301	-.102	1.85
A/2.3	SOVODENJ	A	2.40	.711	-.041	2.800	-.015	2.38
A/11.7	SOVODENJ	A	3.03	1.126	.521	2.509	.745	3.00
A/13.0	SOVODENJ	A	2.72	.787	.326	3.477	.159	2.70
A/17.1	SOVODENJ	A	2.78	.791	.442	3.006	.128	2.78
A/25.0	SOVODENJ	A	2.11	.791	.284	2.719	.141	2.10
A/29.2	SOVODENJ	A	3.55	.908	.238	2.499	.178	2.53
A/29.5	SOVODENJ	A	2.32	.698	.920	3.787	.312	2.27
A/31.6	SOVODENJ	A	2.24	.741	.321	3.620	.131	2.18
A/33.4	SOVODENJ	A	3.52	.887	.806	3.004	.562	3.43
A/34.1	SOVODENJ	A	2.29	.839	.916	4.068	.541	2.28
A/38.0	SOVODENJ	A	1.66	.713	.266	2.693	.097	1.63
A/50.0	SOVODENJ	A	4.86	.591	-.304	1.920	-.063	5.28
A/56.3	SOVODENJ	A	1.59	.811	.192	2.741	.103	1.57
A/65.5	SOVODENJ	A	1.85	.685	.880	3.521	.283	1.83
A/90.0	SOVODENJ	A	3.30	.823	.417	3.111	.232	3.30
A/100.0	SOVODENJ	A	3.51	.717	.350	3.152	.129	3.50
A/104.4	SOVODENJ	A	3.68	.713	.406	2.803	.147	3.75
A/104.5	SOVODENJ	A	2.77	.944	.874	3.338	.734	2.75
A/113.0	SOVODENJ	A	1.35	.802	-.028	3.020	-.014	1.40
B1/11.0	SOVODENJ	B	2.24	.766	.239	2.742	.107	2.22
B1/8.0	SOVODENJ	B	3.18	.677	.303	3.411	.094	3.18
B1/7.0	SOVODENJ	B	1.40	.661	.276	2.720	.080	1.40
B1/4.5	SOVODENJ	B	1.56	.656	.278	3.111	.078	1.60
B2/10.3	SOVODENJ	B	2.09	.715	.446	3.327	.163	2.02
B2/4.7	SOVODENJ	B	3.71	.739	.087	2.792	.035	3.70
C/0.7	SOVODENJ	C	3.81	.583	.523	3.589	.104	3.82
C/2.2	SOVODENJ	C	3.73	.595	.459	3.041	.096	3.72
C/6.3	SOVODENJ	C	4.31	.724	-.140	2.588	-.053	4.30
C/6.6	SOVODENJ	C	4.19	.628	.156	3.069	.039	4.18

SI	SKI	KG	C	MD	QDa	MCD	Ro	Sa	Su	ϕSu	BL%
.591	.165	1.171	.732	.330	.081	.139	0	2	0		100
.658	.107	1.061	.841	.308	.090	.403	0	2	0	2.50	93
.631	-.020	1.013	1.866	.660	.201	.113	0	1	0		100
.630	.035	1.340	.732	.277	.078	.123	0	1	1	2.60	90
.910	.161	1.130	.707	.225	.101	.424	0	2	0		100
.500	.045	1.270	.841	.406	.094	.119	0	2	0	2.50	98
.640	0.000	1.170	.841	.297	.094	.003	0	1	0		100
.550	-.018	1.130	.366	.171	.050	.157	0	2	1	3.50	95
.650	.135	1.180	.901	.366	.104	.044	1	2	0		100
.470	.410	.690	.467	.308	.086	-.015	0	-2	0		100
.640	0.000	1.240	.483	.183	.056	.040	0	2	0		100
.610	.061	1.280	.297	.129	.036	.168	0	2	1	3.60	88
.590	.115	1.250	.683	.241	.066	.096	0	-2	1	3.20	96
.530	.075	1.060	.595	.277	.078	.020	0	1	0		100
.580	.143	1.500	.287	.139	.034	.166	0	2	1	3.40	84
.560	.100	1.420	.435	.196	.044	.064	0	2	0		100
.660	.272	1.110	.210	.095	.029	.251	0	-2	1	3.50	60
.500	.056	1.310	.319	.139	.031	.016	0	-2	1	3.50	90
.800	.199	.500	.420	.177	.062	.522	0	2	1	3.50	87
.650	.214	1.290	.354	.165	.047	.237	0	2	1	3.50	90
.710	-.008	.500	.901	.287	.087	.059	0	-2	1	2.30	78
.630	.079	.550	.500	.189	.053	.110	0	1	1	3.00	84
.750	.146	1.110	.435	.165	.064	.341	0	2	1	3.50	90
.660	.168	1.290	.467	.196	.056	.150	0	2	0		100
.670	.138	1.220	.435	.189	.060	.222	0	2	1	3.20	88
.698	.087	1.257	.259	.113	.030	.329	0	2	1	3.30	72
.658	.023	1.000	.500	.177	.056	.058	0	1	0		100
.643	0.000	1.148	.420	.154	.041	.061	0	1	0		100
.523	.028	1.054	.518	.225	.055	.058	0	1	1	2.50	86
.500	-.015	1.040	.435	.159	.037	.054	0	1	0		100
.483	.059	1.208	.483	.218	.049	.101	0	1	1	2.60	91
.543	.037	1.083	.483	.210	.052	.095	0	1	1	2.50	82
.575	.048	1.038	.683	.241	.065	.015	0	-2	1	2.30	80
.591	.072	1.025	.683	.420	.118	.078	0	2	0		100
.578	.050	1.171	.467	.196	.050	.073	0	1	1	2.50	80
.508	.188	.995	.683	.342	.081	.065	0	2	1	2.50	97
.623	.145	.988	.683	.287	.081	.075	0	2	0		100
.590	.140	1.430	.966	.420	.103	.117	0	2	0		100
.680	.099	1.050	.901	.366	.129	.077	0	2	0		100
.618	.089	1.148	.595	.233	.060	.092	0	2	0		100
.618	-.065	1.013	.555	.196	.060	.106	0	1	1	3.50	99
.643	.015	1.013	.536	.183	.054	.061	0	1	1	3.30	96
.746	.171	1.004	.758	.297	.098	.179	0	2	1	3.00	97
.820	.009	1.024	1.464	.277	.094	-.102	1	1	1	2.90	92
.726	-.017	1.035	1.231	.189	.065	-.015	0	1	0		100
1.123	.495	.978	.500	.149	.072	.744	0	1	1	2.60	48
.789	.122	1.034	.500	.159	.058	.159	0	1	1	2.90	60
.646	.191	1.061	.366	.154	.044	.219	0	1	1	2.80	60
.827	.047	.869	.660	.233	.106	.141	0	2	0		100
.857	.056	.934	.555	.088	.036	.178					
.656	.222	1.576	.500	.218	.053	.313	0	1	1	2.60	75
.729	.096	1.138	.660	.225	.071	.131	0	1	1	2.70	80
1.072	.044	1.064	.297	.095	.031	.562	0	1	0		100
.812	.188	1.208	.637	.218	.072	.541	0	1	1	2.50	70
1.033	.081	.902	.871	.330	.117	.096	0	2	0		100
1.015	.161	.807	.080	.027	.016	-.063	0	1	1	4.30	23
.806	.432	.927	1.035	.342	.137	.102	0	2	0		100
.658	.313	1.061	.637	.308	.084	.283	0	2	0		100
.752	.066	1.143	.330	.102	.035	.232	0	1	1	4.50	95
.691	.004	1.025	.268	.088	.028	.129	0	1	0		100
.643	0.000	1.012	.203	.074	.023	.147	0	1	0		100
.915	.279	1.174	.500	.165	.060	.735	0	1	1	2.90	65
.920	.128	1.194	1.569	.392	.158	-.014	0	1	1	2.40	88
.761	.135	.871	.660	.225	.077	.107	0	1	1	2.30	60
.646	.168	1.061	.330	.117	.033	.094	0	-2	1	3.00	58
.643	.024	.956	.966	.379	.120	.080	0	1	1	2.30	90
.603	0.000	1.025	.901	.330	.093	.078	0	1	1	.70	96
.676	.103	1.157	.660	.250	.073	.163	0	1	1	2.80	86
.746	.010	.956	.250	.077	.028	.035	0	1	0		100
.575	.022	.973	.177	.072	.020	.104	0	1	0		100
.583	.035	.999	.196	.077	.022	.097	0	1	0		100
.706	.011	.963	.159	.051	.018	-.053	0	1	1	3.50	6
.616	-.020	.964	.149	.054	.017	.039	0	0	1	2.75	0

CASE NAME	OZP	OZS	M	S	SKEW	KURT	ALFA	MZ
E/212.0	SOVODENJ	E	2.39	.781	.347	2.783	.165	2.42
E/207.3	SOVODENJ	E	2.40	.600	.238	3.329	.051	2.42
E/202.8	SOVODENJ	E	2.56	.579	.191	2.819	.037	2.60
E/197.5	SOVODENJ	E	3.00	.689	.613	3.941	.201	3.03
E/192.3	SOVODENJ	E	1.96	.559	.365	2.901	.064	1.93
E/186.3	SOVODENJ	E	2.17	.650	.475	2.709	.130	2.15
E/178.5	SOVODENJ	E	2.49	.551	.070	2.907	.012	2.50
E/173.7	SOVODENJ	E	2.55	.533	.241	3.077	.036	2.53
E/159.3	SOVODENJ	E	3.29	.547	.162	2.849	.026	3.28
E/154.0	SOVODENJ	E	3.31	.667	.392	3.272	.116	3.33
E/149.0	SOVODENJ	E	2.38	.533	-.478	3.305	-.072	2.43
E/142.3	SOVODENJ	E	3.46	.628	.682	3.698	.169	3.40
E/135.0	SOVODENJ	E	3.03	.650	.316	3.512	.087	3.03
E/126.4	SOVODENJ	E	3.43	.680	.571	3.333	.180	3.40
E/122.0	SOVODENJ	E	2.63	.595	.350	3.002	.074	2.63
E/119.5	SOVODENJ	E	2.48	.626	.312	3.175	.077	2.50
E/110.8	SOVODENJ	E	4.25	.713	.118	2.601	.043	4.25
E/108.4	SOVODENJ	E	2.29	.662	.233	3.044	.068	2.27
E/99.4	SOVODENJ	E	2.50	.627	-.026	3.124	-.006	2.50
E/93.8	SOVODENJ	E	1.67	.699	.116	2.568	.040	1.63
E/93.0	SOVODENJ	E	2.05	.587	.331	3.268	.067	2.02
E/88.2	SOVODENJ	E	1.79	.551	.126	3.053	.021	1.75
E/80.7	SOVODENJ	E	2.22	.738	.378	2.651	.152	2.18
E/80.4	SOVODENJ	E	2.33	.517	.342	3.156	.047	2.28
E/78.4	SOVODENJ	E	3.41	.635	.387	2.809	.099	3.47
E/74.4	SOVODENJ	E	2.08	.650	.311	3.722	.085	2.08
E/72.7	SOVODENJ	E	1.33	.765	.129	2.791	.058	1.35
E/71.5	SOVODENJ	E	2.09	.742	.636	3.255	.260	2.05
E/69.4	SOVODENJ	E	1.71	.763	.027	3.014	.012	1.78
E/64.7	SOVODENJ	E	3.25	.594	.746	4.394	.156	3.27
E/61.0	SOVODENJ	E	2.71	.619	.074	2.563	.018	2.75
E/52.0	SOVODENJ	E	3.23	.597	.346	2.991	.074	3.10
E/45.7	SOVODENJ	E	1.15	.634	-.356	3.330	-.091	1.15
E/44.4	SOVODENJ	E	2.25	.686	.365	3.257	.118	2.27
E/35.1	SOVODENJ	E	2.70	.771	.488	3.301	.224	2.68
E/23.3	SOVODENJ	E	1.87	.634	.275	3.305	.070	1.85
E/14.4	SOVODENJ	E	1.56	.752	.428	2.559	.182	1.53
E/9.3	SOVODENJ	E	2.09	.592	.481	3.085	.100	2.08
E/8.8	SOVODENJ	E	1.38	.627	.304	3.015	.075	1.38
E/6.5	SOVODENJ	E	1.69	.649	.510	3.846	.139	1.63
D/82.3	SOVODENJ	D	1.85	.601	.350	3.347	.076	1.82
D/69.5	SOVODENJ	D	2.26	.627	.515	3.652	.127	2.28
D/68.4	SOVODENJ	D	1.43	.620	.034	2.689	.008	1.42
D/54.0	SOVODENJ	D	.78	.678	-.102	3.317	-.032	.77
D/52.0	SOVODENJ	D	1.12	.666	-.143	2.842	-.042	1.13
D/30.5	SOVODENJ	D	1.07	.675	.152	3.119	.047	1.07
D/27.5	SOVODENJ	D	1.40	.682	.353	2.883	.112	1.43
D/25.5	SOVODENJ	D	1.30	.722	.126	2.204	.047	1.30
D/17.9	SOVODENJ	D	1.19	.585	-.210	3.792	-.042	1.18
D/15.0	SOVODENJ	D	1.57	.850	-.261	3.077	-.161	1.58
S/5	SKOFJE	S	2.37	.688	.168	3.039	.055	2.37
S/4/2	SKOFJE	S	2.85	.587	.366	3.331	.074	2.87
S/2	SKOFJE	S	2.58	.617	-.120	2.800	-.028	2.55
S/1	SKOFJE	S	2.40	.674	.521	2.894	.159	3.37
V2/14.87	SKOFJE	V2	1.96	.686	.315	2.509	.102	1.97
V2/18.9	SKOFJE	V2	1.78	.666	.166	2.596	.049	1.83
V2/21.3	SKOFJE	V2	2.14	.635	.175	2.730	.045	2.18
V2/24.0	SKOFJE	V2	1.85	.582	.256	3.159	.051	1.87
V2/26.25	SKOFJE	V2	2.16	.596	.273	2.399	.058	2.17
V20/217.0	SKOFJE	V20	1.84	.648	.656	3.654	.178	1.80
V20/217.4	SKOFJE	V20	1.56	.592	.207	2.648	.043	1.57
V25/93.5	SKOFJE	V25	2.34	.752	.127	2.862	.054	2.35
V25/100.4	SKOFJE	V25	1.95	.706	.904	4.245	.318	1.95

Symbols for variables of granulometric parameters are evident from the text; OZS – segments, profiles on the galeries in the uranium mine of Žrovski vrh P 10, H53-54, H52 on the surface KL, RA1, Ra2, RA3, GV, A, B, C, D, E, S and the cores B74, V2, V20, V25

SI	SKI	KG	C	MD	QDa	MCD	Ro	Sa	Su	ϕSu	BL%
.749	.189	.995	.574	.203	.072	.165	0	1	1	2.40	55
.636	.087	1.450	.500	.189	.044	.051	0	-2	1	2.70	77
.595	.013	.999	.406	.165	.046	.037	0	1	0		100
.658	.084	1.127	.330	.125	.035	.201	0	1	1	3.30	70
.555	.330	1.083	.555	.287	.063	.064	0	2	0		100
.678	.178	1.025	.500	.233	.071	.130	0	2	1	2.40	68
.548	0.000	.984	.435	.177	.046	.012	0	1	0		100
.523	.106	1.230	.379	.177	.037	.036	0	1	1	2.90	78
.513	-.039	.966	.233	.102	.026	.027	0	1	0		100
.623	.185	.988	.297	.105	.030	.116	0	-2	1	3.3	58
.478	-.129	1.304	.616	.183	.036	-.072	0	-2	0		100
.575	.170	.973	.233	.098	.027	.169	0	1	1	3.30	50
.603	.092	1.025	.354	.125	.035	.087	0	-2	1	2.80	42
.636	.225	.988	.233	.102	.029	.180	0	1	1	3.20	40
.603	.117	1.093	.379	.165	.044	.074	0	1	1	2.90	75
.666	.056	1.085	.483	.177	.054	.077	0	1	1	3.00	82
.681	.032	1.070	.159	.053	.017	.043	0	0	1	2.60	0
.653	.076	1.153	.555	.210	.059	.068	0	1	1	2.80	84
.618	.024	1.070	.518	.177	.050	-.006	0	-2	1	3.10	84
.678	-.030	1.025	.966	.319	.101	.040	0	1	0		100
.558	.088	1.230	.574	.250	.058	.067	0	1	1	2.50	80
.523	.028	1.054	.707	.297	.073	.021	0	1	1	2.30	86
.766	.044	1.025	.595	.218	.077	.152	0	2	0		100
.495	.003	1.161	.435	.203	.043	.047	0	1	1	2.90	90
.575	.022	1.038	.225	.092	.024	.099	0	1	0		100
.626	.100	1.175	.707	.241	.062	.085	0	-2	1	2.60	82
.754	0.000	1.025	1.320	.392	.139	.058	0	1	0		100
.742	.100	1.252	.707	.241	.077	.260	0	1	1	2.80	86
.694	.146	1.014	1.035	.308	.098	.012	0	2	0		100
.543	.064	1.083	.241	.105	.026	.156	0	1	1	4.00	92
.603	0.000	1.025	.406	.149	.042	.018	0	1	0		100
.468	.155	1.011	.259	.113	.029	.074	0	1	1	3.40	68
.588	0.000	.677	1.516	.451	.127	-.091	1	1	0		100
.631	.044	1.013	.574	.210	.062	.118	0	1	1	2.90	84
.751	.025	.937	.435	.154	.058	.224	0	1	1	3.60	90
.618	.023	1.076	.732	.277	.078	.070	0	1	1	2.50	88
.771	.123	1.004	.841	.354	.125	.182	0	2	1	2.80	90
.586	.155	1.293	.536	.241	.056	.100	0	1	1	2.40	77
.598	.015	1.120	.966	.379	.101	.075	0	2	0		100
.606	.026	1.076	.812	.319	.089	.139	0	-2	0		100
.558	.088	1.230	.683	.287	.062	.076	0	1	1	2.40	86
.593	.093	1.148	.536	.210	.056	.127	0	1	1	2.70	80
.623	.032	.988	1.000	.379	.111	.008	0	1	0		100
.656	.073	1.204	5.278	.616	.161	-.032	1	2	0		100
.678	-.030	1.025	1.414	.451	.143	-.042	0	1	0		100
.691	.127	1.025	1.414	.500	.153	.047	0	2	0		100
.671	.004	1.061	1.000	.366	.115	.112	0	2	0		100
.728	.104	.802	1.072	.420	.169	.047	0	2	0		100
.530	.064	1.166	1.414	.451	.101	-.042	1	-2	0		100
.822	-.034	.962	1.932	.330	.133	-.160	1	1	0		100
.671	.051	1.002	.595	.196	.062	.055	1	2	0		100
.555	.186	1.011	.354	.144	.036	.074	1	2	1	3.70	93
.603	0.000	.964	.518	.171	.052	-.028	0	1	0		100
.686	.164	.943	.420	.196	.069	.160	0	2	1	3.40	92
.668	.143	.906	.616	.268	.088	.102	0	2	1	2.80	86
.646	.145	1.002	.812	.297	.091	.049	0	1	0		100
.636	-.114	.934	.595	.210	.071	.045	0	2	0		100
.560	.006	.948	.707	.277	.078	.050	1	2	0		100
.588	.162	.916	.500	.233	.066	.058	0	2	0		100
.618	.071	1.076	.637	.287	.081	.178	0	2	1	2.50	86
.595	.147	.999	.841	.354	.096	.043	0	2	0		100
.784	.056	1.107	.637	.196	.069	.054	0	1	1	3.20	88
.679	.285	1.281	.707	.277	.073	.318	0	2	1	2.80	88

Oznake spremenljivk, granulometričnih parametrov so razvidne iz tekasta; OZS – segmenti, profili v rovih rudnika urana Žirovski vrh P10, H53-54, H52, na površini KL, RA1, RA2, RA3, GV, PR, A, B, C, D, E, S in vrtinah B74, V2, V20, V25

Table 2. Descriptive statistics of some granulomertic parameters

Tabela 2. Opisne statistike nekaterih granulometričnih parametrov

sprem.	N	min	max	M	SD	SK	KU
M	209	.75	4.86	2.16	.76	.65	.51
S	209	.45	1.13	.68	.09	.93	1.94
SKEW	209	-.53	1.26	.33	.31	.18	.17
KURT	209	1.89	6.32	3.18	.57	1.38	4.33
MZ	209	.55	5.28	2.16	.76	.69	.98
SI	209	.45	1.12	.66	.11	1.17	2.49
SKI	209	-.76	.50	.07	.11	-1.34	13.64
KG	209	.50	1.58	1.06	.15	-.17	3.31
C	209	-.08	5.28	.73	.50	4.07	31.51
MD	209	.03	.66	.26	.12	.76	.35

sprem. – symbols for variables of granulometric parameters are evident from the text; N – number of cases (samples); min – minimal value; M – main; SD – standard deviation; SK – skewness; KU – kurtosis

sprem. – oznake spremenljivk so razvidne iz teksta; N – število enot (vzorcev); min – minimalna vrednost; max – maksimalna vrednost; M – srednja vrednost; SD – standardni odkoln; SK – asimetričnost; KU – sploščenost

A relatively good correspondence of the graphic and the moment measures for the mean and the standard deviation can be seen in the table 2. The lengths of long axes of sections of quartz grains in the examined samples vary from 6.09 Φ (0.015 mm) to -2.4 Φ (5.3 mm) with the mean of 2.16 Φ (0.22 mm). The grains are from poorly to well sorted, on the average moderately well sorted, and their distributions are mainly symmetric. The distributions are very positively to very negatively skewed in the extremes. With respect to the kurtosis, the curves are mostly mesokurtic, but some very platykurtic or very leptokurtic curves could also be observed. The descriptive terms used are related to the quantitative limits as reported by Folk and Ward (1957). In general, the distributions of grain size in the analyzed samples are close to normal with the mean size of 2.16 Φ (0.22 mm) and the average standard deviation of 0.68 Φ (0.094 mm).

Discussion and interpretation

The analysis of the distribution of grain size and its interpretation can be approached in two ways. In the first one, the cumulative frequency distribution curve of grain size is regarded as a whole, and it is attempted to be interpreted on the basis of hydrodynamic characteristics. In the second way, the characteristics of statistic parameters of distributions of grain size from known recent depositional environments are considered and attempts are made to determine empirically the discriminant functions between them.

One of the pioneers of the study of cumulative frequency curves was Doeglas (1946). He found that grain sizes follow the arithmetic probability function, and that their distributions represent a mixture of two or more populations that are the consequence of various mechanisms of transport. Inman (1949) distinguished three basic types of transport: rolling, sliding and saltation on the bottom, and suspension. He also contributed some thoughts on the graphic parameters of grain size distribution: mean grain size, sorting (standard deviation) and skewness. Sindowski (1957) continued Doeglas's work, but he utilized the log-probability diagrams for representing the cumulative frequency curves, and he empirically subdivided them into groups that belong to sediments of various depositional environments: aeolic, limnic, estuarine, littoral and shelf environment. Moss (1962, 1963) believed that the grain size distribution consists of normally distributed subpopulations that are transported by rolling-sliding, saltation and in suspension. The individual subpopulations have their mean size and sorting. Later Visher (1965) studied the dependence of grain size distribution on the sedimentary structures in fluviatile deposits and the various depositional processes in diverse depositional environments (Visher, 1969).

Based on these concepts an attempt was made to determine the individual genetic populations from the cumulative frequency curves. All three populations of grain sizes, transported by either rolling and sliding (Ro), saltation (Sa) and in suspension (Su), could be determined in the examined samples. Their presence is shown in table 1. In the same table the position of the inflection point between the saltation and suspension populations is presented. This point is estimated according to the maximum grain size in suspension (ΦSu) and the amount of grains that were transported as a bedload (BL %), by rolling or sliding and saltation.

The basic cumulative frequency distribution curves are shown in figure 1.

The presence of rolling and sliding populations could be established only in 5.26 % of the 209 analyzed samples. When present, their amount varied from 1.5 to 16.0 % with an average of 5.9 %. The minimum size of the mentioned subpopulation is 0.75 Φ (0.6 mm) to 0.2 Φ (0.87 mm), with the mean of 0.43 Φ (0.74 mm).

The population of saltation grains was established in 99.04 % of the examined samples. This population occurs as a unique population in 40.8 %, whereas it is divided in the remaining 58.2 % into two subpopulations (Fig. 1b). Their intersection, the inflection point between the two subpopulations of saltation grains, is above the line of unique saltation population in 46.2 % of the cases, and it is marked by a 2 in table 1. This means that the saltation population is positively skewed in 46.2 % of the cases, and contains more smaller grains with respect to their expected amount in a symmetrical normal distribution. In 12 % of samples, this intersection between the two subpopulations occurs below the line that represents the unique saltation population, and is marked by a -2 in table 1. This suggests a negatively skewed saltation population, which contains more larger grains with respect to their expected amount. This indicates a certain hydrodynamic separation even within the population of saltation grains itself, which was already noticed already by Visher (1965, 1969).

The distribution of grain size of the analyzed samples showing that the grains transported as bedload by rolling, sliding and saltation in the thin layer in the bottom, represents no less than 89.2 % of all grains.

The population of suspended grains was established in 52.15 % examined of the samples, and of these only two samples, or 0.05 %, contain only this population of grains. The average amount of suspended population is 10.8 %. The amount of suspension population is 18.65 % on average, taking into account only the samples containing it. The maximum grain size in the suspension population is 2 Φ (0.25 mm) to 4.50 Φ (0.04 mm), and on average 2.90 Φ (0.15 mm), with standard deviation of 0.51 Φ (0.05 mm).

With respect to comparisons of presented data (Tab. 1) with those of Visher (1969, 1104, Tab.1), the analyzed distribution of grain sizes are interpreted as a product of fluvial sedimentary environment. The detailed hydrodynamic interpretations, as made on the basis of grain size distribution by Middleton (1976), Breyer

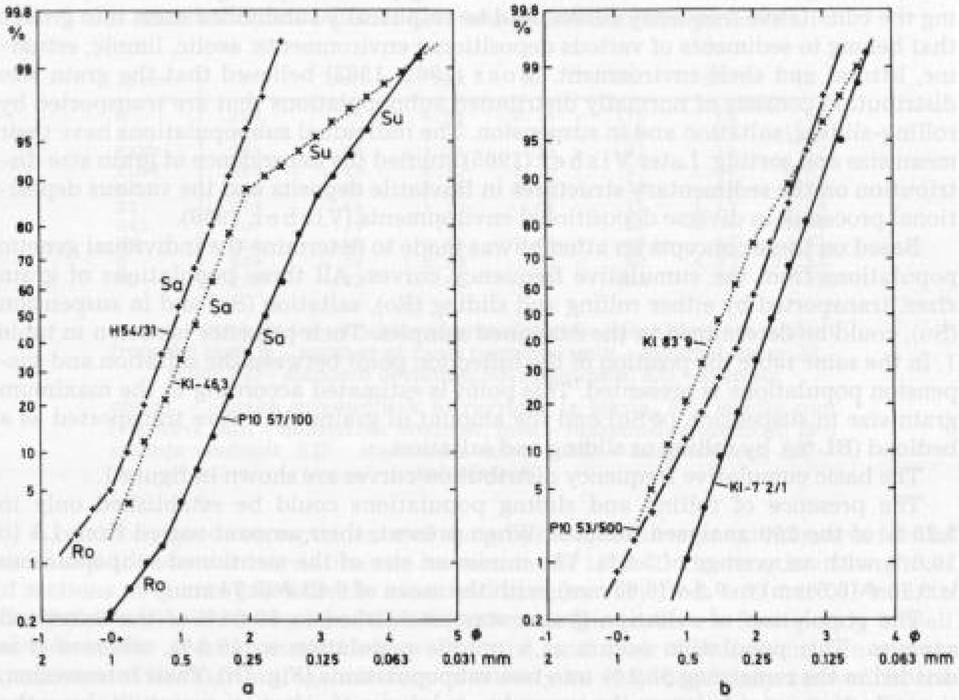

Fig. 1. Basic groups of cumulative grain size distribution curves for the analyzed samples with genetic interpretation: a) Ro -rolling-sliding, Sa – saltation, and Su – suspension populations of grains; b) cumulative distribution curve represented by a single saltation population (Kl-7.2/1) or by two subpopulations that form a positively skewed (Kl-83.9) and a negatively skewed (P10 53/500) saltation population

Sl. 1. Osnovne skupine kumulativnih porazdelitvenih krivulj velikosti zrn analiziranih vzorcev z genetsko interpretacijo: a) Ro – populacija kotalečih – drsečih, Sa – poskakujočih, Su – suspendiranih zrn; b) kumulativna porazdelitvena krivulja, predstavljena z eno populacijo (Kl-7,2/1) ali dvema podpopulacijama, ki sestavljata pozitivno asimetrično (Kl-83,9) in negativno asimetrično (P10 53/500) populacijo poskakujočih zrn

(1979) and others, are beyond the frame of the present study. Only that Middleton (1976) determined the average shear velocity of the transporting medium on the basis of the interruption (position of inflection point) between the populations of grain sizes that are transported by rolling and sliding, and the population of grain sizes in intermittent suspension that coincides with the lower part of the population of saltation grains shall be mentioned.

In study of dynamics during the transport and sedimentation, Passega (1957, 1964) utilized the ratios between the largest grains at 1 % on the cumulative curve (C) and the median (Md) in metric units, of a larger number of homogenous, but structurally diverse samples. The importance of maximum size that should reflect the maximum power of the current, was also recognized by other researchers.

Passega (1957, 1964) distinguished two modes of transport: rolling and suspension. He further subdivided the suspension into the graded and homogenous suspension at the bottom, and the pelagic suspension. The Passega's (1957, 1964) diagram in which the data of analyzed samples were plotted, shows that the prevailing part of the material was transported in form of the graded bottom suspension that could correspond to the saltation population (Moss, 1962, 1963; Visher, 1969).

Besides the hydrodynamic interpretation of the cumulative frequency distribution function and its importance for the hydrodynamic of the depositional environment the graphic and the moment statistical parameters were also considered.

The factor analysis (Skaberne & Smolej, 1981) indicated that the mean grain size and the skewness are interrelated. They are loading the first factor with the highest loadings by skewness. The second factor is defined by the standard deviation and the kurtosis, with the highest loadings by the standard deviation. The scatterplots of independent variables of the graphic mean grain size (MZ) versus the inclusive graphic standard deviation (SI) that separate the aeolic and the fluvial sediments (Friedman, 1961), the beach and the fluvial sediments (Friedman, 1967); the shore bars and the fluvial sediments (Moiola & Weiser, 1986) were therefore tested. According to the discriminant function of Moiola and Weiser (1968) all the analyzed samples were attributed to the fluvial deposits, whereas the solution on the ground of Friedman's diagrams (1961, 1967) is not significant.

A better resolution between the beach and the fluvial deposits provide Friedman's diagrams of the inclusive graphic standard deviation (SI) versus the inclusive graphic skewness (SKI) (Fig. 2a) (Friedman, 1967) by which 85.6 % of studied samples were attributed to the fluvial deposits. An even better resolution was given by the bivariate diagram of the moment derived standard deviation (S) versus the mean cubic deviation (MCD) (Fig. 2b), (Friedman, 1967), in which no less than 95.7 % of analyzed samples plot in the field of fluvial deposits.

An interesting diagram for defining the depositional environments on the basis of granulometric parameters of the median (MD) versus the arithmetic quartile deviation (QDa) in metric units was proposed by Buller and Mc Manus (1972). The diagram discriminates between the "quietwater", fluvial, eolic and beach deposits (Fig. 3). In the envelope of the fluvial sediments plot no less than 97.6 % of the analyzed samples.

Conclusion

The grain size and its distribution are influenced by a multitude of factors which limits their application for the interpretation of the paleodepositional environment. In case of their use also other relevant criteria, such as the sedimentary structures, spatial succession of facies, fossils, other textural parameters, etc. must be taken into consideration.

In the analyzed samples the graphic and the moment derived estimates of the mean grain size and the standard deviation correspond relatively well in spite of open classes on both ends of the distribution curve, whereas the estimates for the skewness and the kurtosis correspond somewhat less well.

The distribution of lengths of the long axes of grain sections, as determined in thin sections, can serve in certain cases as a satisfactory approximation to distributions of sizes of real grains. Their representations on log-probability diagrams can be used for interpretation of the mode of transport. Most of the analyzed sandy fraction of the Val Gardena sandstones belongs to the saltation population. The suspension

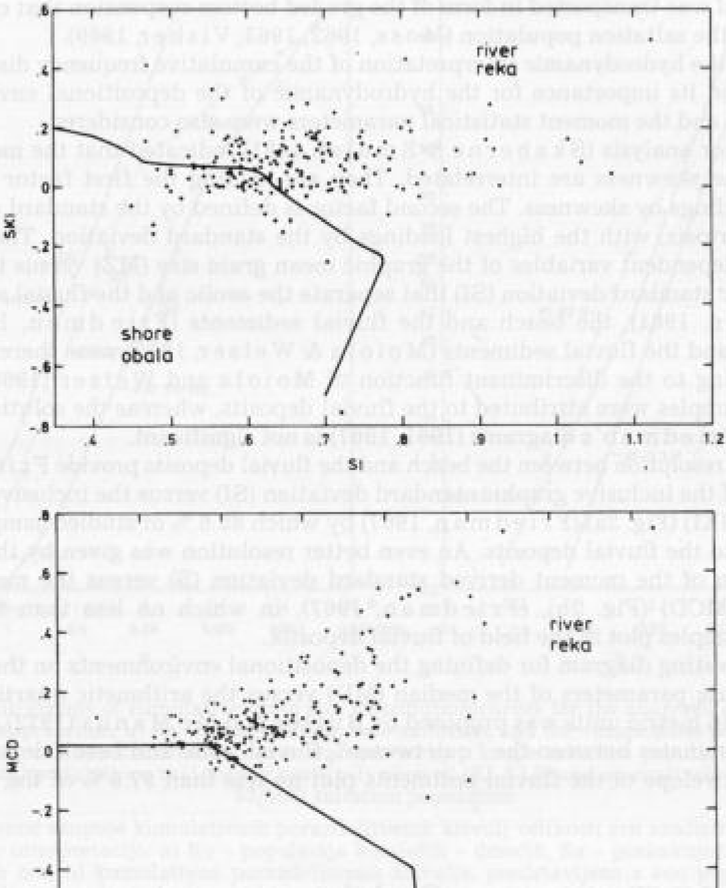

Fig. 2. Scatterplot for distinguishing between the fluvial and beach clastic sediments: a) plot of graphic standard deviation (SI) versus inclusive graphic skewness (SKI); b) plot of standard deviation (S) versus mean cubic deviation (MCD) (Friedman, 1967)

Sl. 2. Bivariatna diagrama za ločitev med rečnimi in obalnimi klastičnimi sedimenti: a) diagram med grafičnim standardnim odklonom (SI) in inkluzivno grafično asimetričnostjo (SKI); b) diagram med standardnim odklonom (S) in srednjim kubiranim odklonom (MSD) (Friedman, 1967)

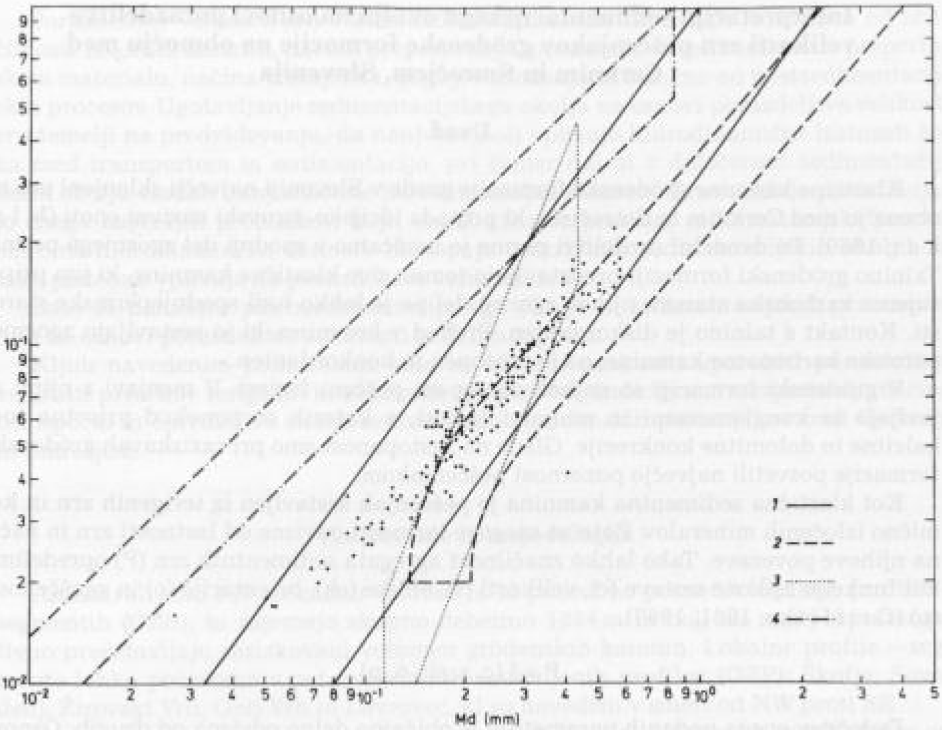

Fig. 3. Scatterplot of metric median (Md) versus quartile deviation (QDa) and their envelopes representing fluvial *(1)*, shore *(2)*, eolian *(3)* and quiet water *(4)* environments (Buller & McManus, 1972)

Sl. 3. Bivariantni diagram med metrično mediano (Md) in kvartilnim odklonom (QDa) s polji, ki opredeljujejo rečne *(1)*, obalne *(2)*, eolske *(3)* in mirnovodne *(4)* sedimente (Buller & McManus, 1972)

population is present in about one half of the analyzed samples, with the average amount of about 20 %. The rolling and sliding population was established only in 5 % of analyzed samples, with the mean amount of about 6 %.

On the basis of statistical parameters of the distribution of lengths of long axes of sections of quartz grains of the Val Gardena sandstones in the area between Cerkno and Sovodenj their depositional environment is interpreted as fluvial. This interpretation is also confirmed by other criteria such as: sedimentary structures, vertical succession of lithofacies and their lateral correlation, etc. (Skaberne, 1995).

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Interpretacija sedimentacijskega okolja na osnovi porazdelitve velikosti zrn peščenjakov grödenske formacije na območju med Cerknim in Smrečjem, Slovenija

Uvod

Klastične kamnine grödenske formacije grade v Sloveniji največji sklenjeni pas na območju med Cerknim in Smrečjem, ki pripada idrijsko-žirovski narivni enoti (Mlakar, 1969). Po dvodelni razdelitvi perma jo uvrščamo v spodnji del zgornjega perma. Talnino grödenski formaciji predstavljajo temno sive klastične kamnine, ki jim pripisujemo karbonsko starost, njihov zgornji del pa je lahko tudi spodnjepermske starosti. Kontakt s talnino je diskordanten. Prehod v krovnino, ki jo sestavljajo zgornjepermske karbonatne kamnine, pa je postopen in konkordanten.

V grödenski formaciji so najbolj zastopani peščeni faciesi. V menjavi z njimi se javljajo še konglomeratni in muljasti faciesi, v katerih so ponekod prisotne tudi kalcitne in dolomitne konkrecije. Glede na zastopanost smo pri raziskavah grödenske formacije posvetili največjo pozornost peščenjakom.

Kot klastična sedimentna kamnina je peščenjak sestavljen iz terigenih zrn in kemično izločenih mineralov. Zato so njegove lastnosti odvisne od lastnosti zrn in načina njihove povezave. Tako lahko značilnost agregata sedimentnih zrn (P) opredelimo kot funkcijo njihove sestave (c), velikosti (s), oblike (sh), orientacije (o) in zgoščenosti (p) (Griffiths, 1961, 1967).

$$P = f\,(c, s, sh, o, p)$$

Določitev enega podanih parametrov je običajno delno odvisna od drugih. Osnovne lastnosti trdno vezanih kamnin, ki se ne dajo dezintegrirati na posamezna zrna brez vpliva na njihovo prvotno velikost in obliko, lahko določamo le v zbruskih. V tem primeru se navedenim pridruži še ena spremenljivka, to je smer preseka prek agregata zrn kamnine.

V nadaljevanju se bomo od navedenih lastnosti omejili na velikost oziroma porazdelitev velikosti terigenih zrn v obravnavanih kamninah.

Velikost zrn peskov in peščenjakov, ki se dajo dezintegrirati na posamezna zrna, običajno določamo s sejanjem. Pri dezintegraciji pa uničimo povezave med zrni oziroma njihov zlog, ki ga opredeljujemo z orientacijo (o) in zgoščenostjo (p) zrn. Tako je določitev velikosti zrn (P_s) odvisna le še od sestave (c), velikosti (s) in oblike (sh) zrn.

$$P_s = f\,(c, s, sh)$$

Zaradi pomembnosti velikosti zrn oziroma njihove porazdelitve v peščenjakih tako iz tehničnega kakor iz genetskega vidika so različni avtorji (Friedman, 1958, 1962; Adams, 1977; Harrell & Eriksson, 1979; Johnson, 1994) skušali določiti korekcijske faktorje za spremembo v zbruskih določene velikosti presekov zrn v velikosti zrn, opredeljenih s sejalno metodo. Pri tem se srečujemo s problemi definicije velikosti, ki je odvisna od uporabljene metode (Allen, 1968) in določitvijo "prave" velikosti v zbruskih, ki predstavlja tudi matematični problem. Analiza omenjenih problemov presega naš okvir in jih je v novejšem času obravnaval Johnson (1994).

V sedimentni petrologiji se že od nekdaj prizadevajo uporabiti zrnavost sedimenta za določitev okolja njihovega nastanka.

Porazdelitev velikosti zrn v klastičnih sedimentnih kamninah je odvisna od značilnosti izvornih kamnin, načina preperevanja, porazdelitve velikosti zrn v preperinskem materialu, načina transporta, pogojev usedanja in končno od postsedimentacijskih procesov. Ugotavljanje sedimentacijskega okolja na osnovi porazdelitve velikosti zrn temelji na predvidevanju, da nanjo najbolj vplivajo hidrodinamične lastnosti toka med transportom in sedimentacijo, pri čemer naj bi v določenem sedimentacijskem okolju vladale zanj značilne hidrodinamične razmere. Prav slednje predstavljajo enega največjih problemov, kajti enaki ali zelo podobni sedimentacijski procesi oziroma hidrodinamične razmere nastopajo v različnih sedimentacijskih okoljih in tako podobno vplivajo na porazdelitve velikosti zrn.

Zato so določitve paleosedimentacijskega okolja in sedimentacijskih procesov v njih na osnovi porazdelitve zrnavosti le delno uspešni.

Kljub navedenim pomislekom smo se odločili poskusiti uporabiti porazdelitve velikosti presekov terigenih kremenovih zrn peščene frakcije za interpretacijo načina transporta in opredelitve okolja sedimentacije grödenskih peščenjakov med Cerknim in Smrečjem.

Vzorčevanje in metodologija

Analizirali smo 209 točkastih vzorcev iz 18 podrobno posnetih lokalnih profilih – segmentih (OZS), ki zajemajo skupno debelino 1234 m in bolj ali manj reprezentativno predstavljajo raziskovani volumen grödenskih kamnin. Lokalne profile – segmente lahko povežemo v pet regionalnih sestavljenih profilov (OZP): Škofje, Sovodenj, Žirovski Vrh, Goli Vrh in Lavrovec, ki so navedeni v smeri od NW proti SE.

V zbruskih smo pri povečavi 150× z mikrometrskim okularjem merili dolge osi 200 kremenovih zrn. Kremenova zrna so bila slučajno določena s točkovnim števcem. Z izborom ene vrste terigenih, kremenovih zrn smo zmanjšali vpliv sestave na določanje velikosti. V sestavi grödenskih peščenjakov so kremenova zrna tudi najbolj zastopana, saj predstavljajo poprečno 63 % populacije vseh terigenih zrn. Dolžine presekov smo razdelili do velikosti 5 Φ (0.03 mm) na razrede, široke 1/4 Φ, nato pa na razrede 1/2 Φ do najmanjše merjene velikosti 7 Φ (0.008 mm). Na osnovi teh podatkov smo izračunali relativne in kumulativne frekvence, ki so služile za nadaljnjo analizo.

Rezultati

Na osnovi kumulativnih relativnih frekvenc smo izrisali kumulativne porazdelitvene krivulje dolgih osi presekov kremenovih zrn s Φ skalo na abcisi in z verjetnostno skalo na ordinati. Iz kumulativne porazdelitvene krivulje smo odčitali vrednosti za izračun grafičnih statističnih parametrov (Folk & Ward, 1957): grafično srednjo vrednost velikosti (MZ), inkluzivni grafični standardni odklon (SI), inkluzivno grafično asimetričnost (SKI) in grafično sploščenost (KG). Poleg tega smo podali velikosti v mm pri 1 % (C) in mediano (MD) ter izračunali kvartilni odklon (QDa) (Buller & Mc Manus, 1972). Kljub težavam, ki izhajajo iz delno odprtih razredov v območju največjih in najmanjših zrn, na kar opozarja Folk (1966), smo poleg grafičnih statističnih parametrov iz podatkov relativnih frekvenc v razredih 1/4 Φ z momentnim računom izračunali statistične parametre: povprečno velikost (M), standardni odklon (S), asimetričnost (SKEW), sploščenost (KURT), preprosto mero asimetričnosti

(ALFA) in srednji kubirani odklon (MCD) (Friedman, 1967). Navedeni parametri so za posamezne analizirane vzorce zbrani v tabeli 1, opisne statistike granulometričnih statističnih parametrov pa podajamo v tabeli 2.

Iz tabele 2 je razvidno, da se grafične in momentne vrednosti za srednjo vrednost in standardni odklon sorazmerno dobro ujemajo. Velikost dolgih osi presekov kremenovih zrn se v raziskanih vzorcih spreminja od 6,0 *Φ* (0,015 mm) do -2,4 *Φ* (5,3 mm) in znaša povprečno 2,16 *Φ* (0,22 mm). Zrna so slabo do dobro, poprečno srednje dobro sortirana, medtem ko so njihove porazdelitve večinoma simetrične. V ekstremih so porazdelitve zelo pozitivno do zelo negativno asimetrične. Če pogledamo sploščenost, vidimo, da so krivulje večidel normalne (mezokurtične), zasledimo pa tudi zelo sploščene ali zelo ošiljene krivulje. Navedeni opisni izrazi se nanašajo na kvantitativne meje, ki jih podajata Folk in Ward (1957). V splošnem lahko rečemo, da so porazdelitve velikosti zrn v raziskanih vzorcih relativno normalne s povprečno velikostjo 2,16 *Φ* (0,22 mm) in povprečnim standardnim odklonom 0,68 *Φ* (0,094 mm).

Razprava

Analize porazdelitve velikosti zrn in njene interpretacije se lahko lotimo na dva načina. V enem upoštevamo kumulativno krivuljo porazdelitve velikosti zrn kot celoto in jo skušamo interpretirati na osnovi hidrodinamičnih značilnosti. V drugem primeru pa obravnavamo značilnosti statističnih parametrov porazdelitev velikosti zrn iz znanih, recentnih sedimentacijskih okolij in skušamo med njimi empirično ugotoviti diskriminantne funkcije.

Eden izmed pionirjev preučevanja oblike kumulativnih krivulj je bil Doeglas (1946). Ugotovil je, da velikosti zrn slede aritmetični verjetnostni funkciji in da njihove porazdelitve predstavljajo mešanico dveh ali več populacij, ki so posledice različnih mehanizmov transporta. Inman (1949) je v transportu prepoznal tri osnovne tipe: kotaljenje ali drsenje in poskakovanje po dnu ter suspenzijo. Poleg tega je podal nekaj misli o grafičnih parametrih porazdelitve velikosti zrn: srednja velikost, sortiranost (standardni odklon) in asimetričnost. Sindowski (1957) je nadaljeval delo Doeglasa, vendar je uporabljal log-verjetnostne diagrame prikazovanja kumulativnih krivulj in jih glede na obliko empirično razdelil v skupine, ki pripadajo sedimentom različnih sedimentacijskih okolij: eolskemu, limničnemu, estuarijskemu, obalnemu in šelfnemu okolju. Moss (1962, 1963) je ugotovil, da je porazdelitev velikosti zrn sestavljena iz normalno porazdeljenih podpopulacij, ki se premikajo s kotaljenjem in drsenjem, poskakovanjem in v suspenziji. Posamezne podpopulacije imajo svojo povprečno velikost in sortiranost. Kasneje je Visher (1965) v rečnih sedimentih preučeval odvisnost porazdelitve velikosti zrn od sedimentnih tekstur in različnih sedimentacijskih procesov v raznolikih sedimentacijskih okoljih (Visher, 1969).

Na osnovi teh spoznanj smo skušali v kumulativnih krivuljah opredeliti posamezne genetske populacije. V raziskanih vzorcih smo lahko določili vse tri populacije velikosti zrn, ki so se premikala s kotaljenjem in drsenjem (Ro), poskakovanjem (Sa) in v suspenziji (Su). Njihova prisotnost je prikazana v tabeli 1. Poleg tega smo v isti tabeli podali položaj prevojne točke med poskakujočo suspenzijsko populacijo. Ta točka je določena z ocenjeno maksimalno velikostjo zrn v suspenziji (*Φ* Su) in odstotkom, količino zrn, ki so se transportirala po dnu z mehanizmi talnega transporta (BL %), s kotaljenjem, drsenjem in poskakovanjem.

Osnovne oblike kumulativnih porazdelitvenih krivulj so prikazane na sliki 1.

Izmed 209 raziskanih vzorcev smo ugotovili le v 5,26 % prisotnost kotaleče in drseče populacije. Ob njeni prisotnosti se njena količina spreminja od 1,5 do 16,0 % in znaša povprečno 5,9 %. Minimalna velikost v omenjeni podpopulaciji je 0,75 Φ (0,6 mm) do 0,2 Φ (0,87 mm), povprečno 0,43 Φ (0,74 mm).

Populacijo poskakujočih zrn smo zasledili v 99,04 % raziskanih vzorcih. Ta populacija sestavlja enotno populacijo v 40,8 %, medtem ko se v preostalih 58,2 % razdeli v dve podpopulaciji (sl. 1 b). Presečišče, prevojna točka med obema podpopulacijama poskakujočih zrn je v 46,2 % primerih nad premico enotne podpopulacije v tabeli 1 označeno z 2. To pomeni, da je poskakujoča populacija zrn v 46,2 % primerih pozitivno asimetrična, oziroma vsebuje več manjših zrn v primerjavi z njihovo pričakovano količino. V 12 % vzorcev je to presečišče med podpopulacijama pod premico, ki predstavlja enotno populacijo poskakujočih zrn v tabeli 1 označena z 2, kar kaže na negativno asimetrično populacijo poskakujočih zrn, oziroma vsebuje več večjih zrn v primerjavi z njihovo pričakovano količino. To kaže na določeno hidrodinamično separacijo tudi v sami populaciji poskakujočih zrn, na kar je opozoril že Visher (1965, 1969).

Če pogledamo porazdelitve velikosti zrn v raziskanih vzorcih, vidimo, da predstavljata populaciji zrn, ki se premikajo s talnim transportom, s kotaljenjem, drsenjem in poskakovanjem v tanki plasti po dnu kar 89,2 % vseh zrn.

Populacija suspenzijskih zrn je bila ugotovljena v 52,15 % raziskanih vzorcev, od tega vsebujeta dva vzorca ali 0,04 % le to populacijo zrn. Povprečna količina suspenzijske populacije znaša 10,8 %. V primeru, da analiziramo le vzorce, ki so vsebovali suspenzijsko populacijo zrn, znaša njena količina povprečno 18,52 %. Maksimalna velikost v suspenzijski populaciji je 2 Φ (0,25 mm) do 4,50 Φ (0,04 mm), povprečno 2,90 Φ (0,15 mm) s standardnim odklonom 0,51 Φ (0,05 mm).

Glede na primerjavo prikazanih podatkov (Tab. 1) z Visherjevimi (1969, 1104, Tab. 1) interpretiramo analizirane porazdelitve velikosti zrn kot produkt rečnega sedimentacijskega okolja. Podrobnejše hidrodinamične interpretacije, kakor so jih na osnovi porazdelitev velikosti zrn izvajali Middleton (1976), Viard in Breyer (1979) in drugi, pa presegajo naš okvir interpretacije. Kljub temu naj omenimo, da je Middleton (1976) na osnovi prekinitve (položaja prevojne točke) med populacijama velikosti zrn, ki se transportirajo s kotaljenjem in drsenjem, in populacijo zrn v prekinjeni suspenziji (intermitted suspension), ki sovpada s spodnjim delom populacije poskakujočih zrn, določil povprečno strižno hitrost transportnega medija.

Pri preučevanju dinamike med transportom in sedimentacijo je Passega (1957, 1964) uporabil razmerja med največjimi zrni pri 1 % na kumulativni krivulji (C) in mediano (Md) v metrskih enotah strukturno raznolikih vzorcev. Pomembnost maksimalne velikosti, ki naj bi odražala največjo moč toka, so prepoznali tudi drugi raziskovalci.

Passega (1957, 1964) je ločil dva načina transporta: kotaljenje in suspenzijo. Suspenzijo je nadalje delil na graduirano in homogeno suspenzijo ob dnu in na pelagično suspenzijo. Na osnovi posameznih načinov transporta je opredelil obalne, rečne in turbiditne tokove in pelagično suspenzijo. Iz Passegovega diagrama (1957, 1964), v katerega smo vnesli podatke analiziranih vzorcev, je razvidno, da se je pretežni del materiala transportiral v obliki graduirane talne suspenzije (graded bottom suspension), kar bi odgovarjalo populaciji poskakujočih zrn (saltation population) (Moss, 1962, 1963; Visher, 1969).

Poleg hidrodinamične interpretacije kumulativne porazdelitvene krivulje in njeno uvrstitev v hidrodinamično sedimentacijsko okolje smo preučevali tudi grafične in momentne statistične parametre.

S faktorsko analizo (Skaberne & Smolej, 1981) smo ugotovili, da sta povprečna velikost in asimetričnost med seboj odvisni in sta vezani na prvi faktor, ki je obremenjen predvsem z asimetričnostjo. Drugi faktor opredeljujeta standardni odklon in sploščenost, pri čemer ga prvi najbolj obremenjuje. Zato smo pregledali le bivariantne diagrame z neodvisnimi spremenljivkami med grafično povprečno velikostjo (MZ) in inkluzivnim grafičnim standardnim odklonom (SI), ki ločuje eolske sipine in rečne sedimente (Friedman, 1961), obalne in rečne sedimente (Friedman, 1967); obalne (obrežne) sipine in rečne sedimente (Moiola & Weiser, 1968). Diskriminantne funkcije Moiola in Weiserja (1968) opredele vse raziskane vzorce kot rečne sedimente, medtem ko določitev na osnovi Friedmanovih diagramov (1961, 1967) ni značilna.

Boljšo ločljivost med obalnimi in rečnimi sedimenti kažeta Friedmanova diagrama med inkluzivnim grafičnim standardnim odklonom (SI) in inkluzivno grafično asimetričnostjo (SKI) (sl. 2a) (Friedman, 1967), v katerem je 85,6 % raziskanih vzorcev opredeljenih kakor rečni sedimenti. Še boljšo ločitev kaže bivariantni diagram med momentno določenim standardnim odklonom (S) in srednjim kubiranim odklonom (MCD) (sl. 2b), (Friedman, 1967), v katerem je kar 95,7 % raziskanih vzorcev v polju rečnih sedimentov.

Zanimiv diagram za opredeljevanje sedimentacijskih okolij na osnovi granulometričnih parametrov med mediano (MD) in aritmetičnim kvartilnim odklonom (QDa) sta podala Buller in Mc Manus (1972). Ta ločuje "mirnovodne", rečne, eolske in obalne sedimente (sl. 3). V polje rečnih sedimentov pade kar 97,6 % raziskanih vzorcev.

Sklepi

Na velikost zrn oziroma njihovo porazdelitev vpliva mnogo dejavnikov, zato je njihova uporaba pri interpretaciji paleosedimentacijskega okolja omejena. Ob njihovi uporabi v te namene pa moramo upoštevati še vse druge relevantne kriterije, npr. sedimentne teksture, prostorsko sosledje faciesov, fosile, druge strukturne parametre itd.

V analiziranih vzorcih se grafični in momentno izračunani podatki srednje velikosti in standardnega odklona, kljub odprtim razredom na obeh koncih porazdelitvene krivulje, relativno dobro ujemajo, medtem ko so razlike pri asimetričnosti in sploščenosti nekoliko večje.

Porazdelitve velikosti presekov zrn, določenih v zbruskih, so lahko v nekih primerih zadovoljiv približek porazdelitvam pravih velikosti zrn. Njihovi prikazi na log – verjetnostih diagramih lahko služijo za interpretacijo načina transporta. Večina raziskane peščene frakcije grödenskih peščenjakov pripada poskakujoči populaciji. Suspenzijska populacija je prisotna v približno polovici analiziranih vzorcev s povprečno količino približno 20 %. Kotaleča in drseča populacija pa je bila ugotovljena le v 5 % analiziranih vzorcev, s povprečno količino približno 6 %.

Na osnovi statističnih parametrov porazdelitev velikosti presekov kremenovih zrn peščenjakov grödenske formacije med Cerknim in Smrečjem interpretiramo okolje njihovega nastanka kot rečno. Tako interpretacijo potrjujejo tudi drugi kriteriji v podrobno posnetih profilih: sedimentne teksture, vertikalno zaporedje litofaciesov in njihova lateralna korelacija itd. (Skaberne, 1995).

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