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PALEOHYDROLOGY OF JURASSIC CONGLOMERATE OF THE CRIMEAN PENINSULA

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ABSTRACT

Conglomerate and sandstone assigned to Upper Jurassic, composes the main ridge of the Crimean Mountains (southeast Europe, Black Sea coast). The conglomerate contains exotic pebbles and cobbles of granite and granodiorite, with the probable source area in the Ukrainian Precambrian massif 400 km to the north. Paleohydrologic parameters and sediment transport mechanisms are examined in regards of methodological research. All paleohydraulic calculations show that these strata were formed during short but very intensive sedimentation episode. The paleohydraulic parameters essentially exceed any modern parameters of catastrophic sedimentation. In spite of conservative calculation and precaution, the results are consistent with the Biblical Flood and inconsistent with standard geological time scales.

INTRODUCTION

Conglomerate and pebble sandstone strata are important for the purpose of inferring ancient hydraulic conditions of sedimentation. This article is a continuation of long-term research on sedimentary formations of the Crimean Peninsula on the Black Sea coast. In Part I of this series [11], the geology of lower structural floors of the Crimean sedimentary sequence was described. It consists mostly of alternating sandstone, siltstone and shale layers (turbidities of Tavrick Formation) and the terrigenous - volcanic complex of the Eksiordian Formation. Both Tavrick and Eksiordian strata are folded and faulted. Numerous geological features of the strata confirm deposition in catastrophic conditions of a great water cataclysm.

In Part II of the series [12], the next structural floor of the Crimean sedimentary sequence is observed. It consists of conglomerate and gravel sandstones assigned to the Upper Jurassic Series, Callovian and Oxfordian Stages, that overlie the Tavrick and Eksiordian rocks with angular unconformity. The erosion surface is mechanical only; it has no evidence of a long interruption in sedimentation.

The conglomerate and sandstone strata have no formal lithostratigraphic name. They are not described as a specific formation. In geological literature they are usually called “Upper Jurassic conglomerates” and “Upper Jurassic sandstones”; therefore, I propose to call it the Demerdji Formation, reflecting the name of the mountain where the formation has its most spectacular exposure.

In the description of the geological structure of Crimea, I use the prevalent terms of the uniformitarian systems of the standard geological column, such as “Triassic”, “Jurassic” and so on. This strata correlation is based upon the biostratigraphic assumption that strata around the globe, which contain the same fossils, are of the same age. Inasmuch as the synchronous nature of such strata is questionable, the absolute dating of these strata is rejected.

Limestones of the Kimmeridgian and Tithonian Stages of the Upper Jurassic System overlie the conglomerates and sandstones with gradational contacts (or sometimes with a paraconformity). Both conglomerate and limestone strata are tectonically tilted.

The Demerdji Formation extends up to 80-100 km from west to east and 20 km from north to south. Thickness of the sequence reaches 750 m. Strata are well exposed on the southeastern slope of Crimean Ridge. In tectonically dropped blocks, the conglomerates descend to the Black Sea coast. On the south flank the conglomerate body is cut off by the fault on the border of the Black Sea depression. Far to the north and on the east and west flanks of the Crimean mountain system, rocks of the Demerdji Formation are overlain by Cretaceous and Cenozoic limestones and marls. In those regions the conglomerate is difficult to access for research. Visible dimensions of the formation are minimal. The complete geometry and dimensions of the conglomerate body are unknown.

SEDIMENTOLOGICAL FEATURES OF THE DEMERDJI FORMATION

The Demerdji Formation is divided into three main stratigraphic members (Figure 1). These members are not homogeneous and the border between these members is not always obvious. Different lithological varieties may exist within individual conglomerate beds. From the bottom to the top these members are:

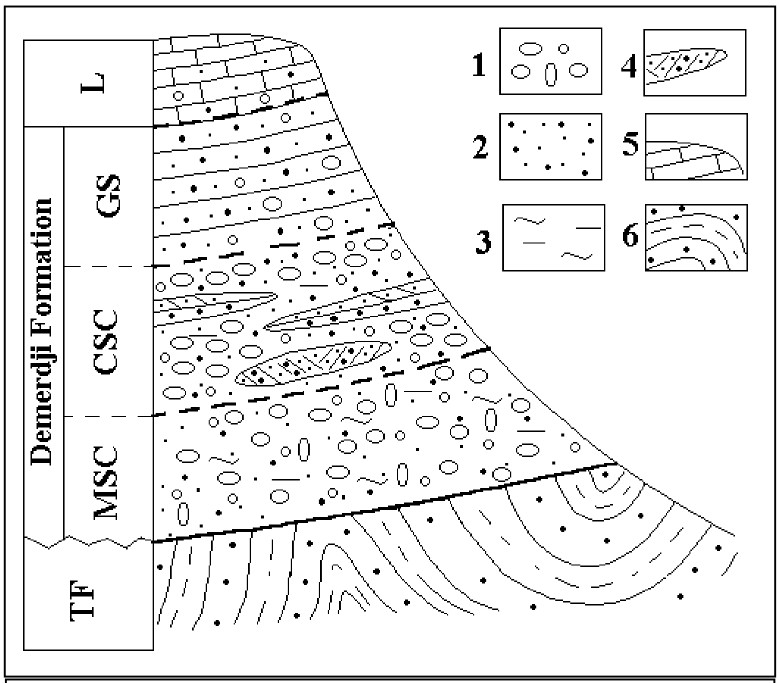

Figure 1. Schematic cross section of Demerji Formation and adjacent strata on the southeast slope of mount Demerdji.
Legend: 1. Pebbles, cobbles and boulders. 2. Heterogranular sand. 3. Silt and clay. 4. Lenses of cross-stratified sandstone. 5. Limestone . 6. Turbidite.
TF - Tavrick Formation, MSC - Matrix-Supported Conglomerate, CSC - Clast-Supported Conglomerate, GS - Gravel Sandstones, L - Limestone.

1. Matrix-Supported Conglomerate (MSC) with mud-sand matrix

This unit is made up a poorly stratified conglomerate whose clasts are supported by a poorly sorted mud-sand matrix. Clast-supported fabric is uncommon and poorly developed. Matrix content is approximately 37%; it consists of heterogranular sand with silt and montmorillonite-hydromica clay [23]. Clay and silt content is up to 30-40% of the matrix. Clasts are pebble to cobble sized, subangular to subrounded. Sometimes boulders up to 0.8 m occur. The clasts have no preferred orientation. Grading was not observed in this member. Sometimes in the upper part of the member 0.3-0.6 m thick and 3-8 m long lenses of coarse cross-bedded sand are observed. Thickness of this member is approximately 300 m.

2. Clast-Supported Conglomerate (CSC) with medium sorted sand matrix

Rocks of this member have clear stratification. We often see alternating sub-facies of clast-supported conglomerates and lenses of cross-stratified coarse to medium sandstones up to 0.4 meter. Within the sandstone layers, matrix-supported fabric is sometimes observed. Matrix content in the conglomerate sub-facies is about 30%. Pebbles and cobbles are mostly medium- to well-rounded. This member has obvious orientation of clasts parallel to bedding planes. Long axes of the clasts have west-southwest to east-northeast orientation. Graded bedding is indicated by decreasing clast size and increasing thickness of sandstones interbeds up section.

Sandstone interbeds consist of coarse- to medium-grained sand with strongly pronounced cross-bedding dipping to the south-southeast. Thickness of cross-bedded units is up to 1-1.5 meters.

Sometimes this member contains exotic well-rounded clasts of biotite-hornblende-feldspar granite and granodiorite. It is notable that granites and granodiorites are exotic in the Crimean Peninsula. The nearest source of the granites is the Ukrainian Shield 400 km to the north [6; 7]. Mathematical modeling of the transport of marked pebbles [13; 14] indicates that at a distance of hundreds of kilometers from the source the content of the pebbles decreases a thousands times and amount to only 0.001% – 0.02% of the pebble content near the source. Thus, low concentration of exotic clasts (along with high roundness) can be evidence of distant transportation of exotic clasts.

Thickness of member 2 is about 250 meter. The upper border of the member is not obvious. The top of the member is identified by a decrease in size and content of gravel, and by increasing thickness of sandstone interbeds.

3. Stratified Gravel Sandstones (GS)

This member includes well- to crudely stratified pebble sandstones. Content of clasts varies from 30-40% in the lower part of the member to 10-15% in the upper part of the member. The sandstone is well- to poorly stratified. The stratification is defined by repetition of fine gravel concentrated interlayers and centimeters-thick, coarse- to medium-grained sand layers that are parallel or inclined at a low angle relative to gravel concentrated interlayers. In the upper part of the member the sandstone is massive and contains calcite cement.

Pebble clasts are smaller than in the underlying member and mostly well-rounded. Very seldom are cobbles up to 0.2 m observed.

Thickness of the unit is about 200 m. The upper boundary of the member varies from a gradual transition (not more than 3-5 meters) to a paraconformity with the overlying limestone. The lowermost limestones contain sand (up to 10%) and fine pebbles of sandstones, siltstones and quartz (not more than 5-10%).

Table 1. GRANULOMETRIC COMPOSITION OF DEMERDJI FORMATION

	Granulometric classes (%)*							d_{max} mm	Standard deviation δ
	<5 mm (matrix)	5-10 mm	10-20 mm	20-40 mm	40-80 mm	80-160 mm	>160 mm		
MSC	37.0 / 37.0	3.0 / 40.0	4.9 / 44.9	13.3 / 58.2	11.4 / 69.6	22.8 / 92.4	7.6 / 100	780	42.8
CSC	28.6 / 28.6	5.4 / 34.0	3.0 / 37.0	19.2 / 56.2	24.2 / 80.4	19.6 / 100	0.0 / 100	370	33.9
GS	69.0 / 69.0	7.3 / 76.3	9.2 / 85.5	9.8 / 95.3	2.0 / 97.3	2.7 / 100	0.0 / 100	200	18.1

* numerator - content of the class; denominator - cumulative percent passing.

The total thickness of the Demerdji Formation reaches up to 750-800 m. Average dimensions of clasts decreases from the bottom to the top of the sequence: average particle size (d_{av}) is 91 mm for the lower member, 62 mm for the middle member and 30 mm for gravel sandstone. Maximum particle diameters (b-axis largest clasts: d_{max}) are 780 mm, 370 mm and 200 mm respectively. Sorting of the sediments improves gradually from the bottom to the top of the sequence. These data suggest that in the Demerdji Formation we observe one transgressive series with a considerable decrease of hydrodynamic power at the end of this sedimentation phase.

Table 2. UNIT PARTICLE SIZE IN MILLIMETERS AT PERCENTILE INDICATED

	d_{50}	d_{84}	d_{90}	d_{95}	$d_{97.5}$	d_{84}/d_{50}
MSC	27	99	130	350	575	3.7
CSC	32	83	90	101	125	2.6
GS	<5	19	25	39	86	>3.8

d_{50}, d_{84}, *etc.* – particle diameter than which 50 (84, *etc.*)% of the bed material is finer.

Granulometric characteristics of Demerdji Formation are displayed in Tables 1 and 2. More detailed description of the deposits is found in [12].

MECHANISM OF SEDIMENT TRANSPORT

Sediment transport processes can be very complex. Depositional characteristics are the result of several processes; therefore determination of depositional characteristics of sediment transport processes by one or two main parameters is not well founded. Hence, depositional process should be characterized on the basis of several criteria. Moreover, inasmuch as various depositional processes may be active simultaneously as a sediment body forms, ratios of main sedimentation processes can change; therefore, various stratigraphic levels within the sediment body may be the result of different depositional processes. For example, sediment traction, saltation and suspension occur simultaneously upon the bed of a river with the proportions of sediment moved by these agents changing with flow velocity, flow velocity gradient and flow depth. Laterally, a debris flow can be diluted with water [19] and be transformed abruptly into a hyperconcentrated flow (the change in rheology is known as “flow transformation”).

Depositional characteristics for various sediment transport mechanisms are indicated in Table 3. The presentation reflects some of the variety of effects produced by particular processes. Attributes of all members of the Demerdji Formation are included in the table for comparison and determination of the most probable sedimentation mechanism.

Comparison of depositional textures and structures within the Demerdji Formation demonstrates that this formation is not a homogeneous sedimentary body. The lower member, for example, is quite distinct from the two higher units. On the other hand, the two upper members, in spite of differences in some characteristics (average size of clasts, sorting, fabric and rounding of clasts), show evidence of a single process. Based on this data, the paleohydrology of the lower unit may be best modeled as a non-Newtonian fluid (hyperconcentrated flow), and the paleohydrology of the middle and upper units as a Newtonian fluid (traction and suspended load).

Table 3. DEPOSITIONAL CHARACTERISTIC OF SEDIMENT TRANSPORT PROCESSES
(after [10, Table 2], with some changes and additions).

Type of flow	ST[1]	GR[2]	SO[3]	IM[4]	CB[5]	RO[6]	CL[7]	MX[8]	DF[9]
Fluvial/Traction and Suspended Current									
Fluvial/Traction Current		N							
Turbidity Current		N/R U							
Mudflow/ Debris Flow		R U					?		
Fluidized Sediment Flow/ Hyperconcentrated Flow		N/R U				?			
Grain Flow/ Debris Flow									
Falls/Slides									
Demerdji Formation									
Matrix-Supported Conglomerate (MSC)									
Clast-Supported Conglomerate (CSC)									
Gravel Sandstone (GS)									

Shading indicates flow type produces deposits exhibiting given attribute; partial shading indicates flow process sometimes produces given attribute depending on other variables.

[1]Stratification
[2]Grading ('N' – Normal, 'R' – Reverse, 'U'-Ungraded)
[3]Sorting
[4]Imbrication
[5]Cross-bedding
[6]Rounding of clasts
[7]Clast-supported fabric
[8]Matrix-supported fabric
[9]Downstream fining

Recognition of hyperconcentrated flow deposits from ancient sequences is hampered by the difficulties in properly estimating the flow properties, such as sediment concentration and rheology, on the basis of deposit characteristics. It is therefore necessary to infer the hyperconcentrated flow process on an approximate and indirect basis.

In general, numerous studies of hyperconcentrated flow [18, 24] show that as a rule it is a two-phase or multiphase flow, in which solid particles (gravel) and interstitial material (matrix particles and water) behave differently. These features lead to density stratification or bipartite division of the flow into a dense and coarse-grained lower part and a dilute and finer grained upper part [20, 26]. Moreover, hyperconcentrated flows have longitudinal zoning [17, 25], so during consecutive phases of the flow development, shift of these zones leads to vertical stratification of the deposits. Therefore, the differences among the members of the formation could result from both bipartite division of a hyperconcentrated flow and changing of flow regime.

According to data displayed in Table 3, the middle (Clast Supported Conglomerate) and especially the upper member (Gravel Sandstone) of the sequence most likely were deposited in conditions of Newtonian flow. It is obvious that sediment transport occurred in different ways for different sediment fractions – bedload for gravel, and suspension for sand-size particles. The suspended constituent is especially important for the upper member, where the sand-size fraction exceeds 70 per cent.

Paleohydraulic conditions were determined by both hyperconcentrated and fluvial models for these members because of uncertainty of sediment transport mechanism. This provides increased degree of confidence in the results.

RECONSTRUCTION OF PALEOHYDRAULIC CONDITIONS

Typical engineering calculations of current parameters are often difficult to apply to paleohydraulic reconstructions, because data available from the research of modern currents (depth and width, for example) are not available for determine of the same parameters in the past. “Various laboratory and field studies have provided data enabling correlation of competence with current speed, flow depth and other hydraulic variables. Defined values for discharge, velocity and other paleohydraulic parameters cannot be provided without historic data; geological data provide only constraints by analogy to observed fluvial processes” [10, p. 371]. Therefore, these methods enable calculation of minimal values; actual flows may have been substantially greater.

Many different methods have been used to reconstruct past flow conditions of fluvial environments. Variables of the stream system commonly considered in paleohydraulic reconstructions include energy gradient, channel depth, fluid density, maximum particle size transported, channel roughness and sedimentary structure. For the lower and middle members of Demerdji Formation, only the methods that pertain to the transport of coarse gravels are relevant, because these particle sizes require the greatest transport energy. But substantial differences between matrix- and clasts-supported conglomerates (mostly in fabric, sorting and presence of significant clay component) demand different methods of paleohydraulic reconstruction. In the upper member, the sand-size material prevails, so that demands one take into account another possible mode of transport.

On the other hand, the differences between subdivisions of Demerdji Formation sometimes are not obvious. There are unclear boundaries between them, and the transitions between adjacent members are determined by quantitative shifts in sedimentary characteristics. Therefore, using all methods to calculate the paleoflow for each member of Demerdji Formation seems most rational. Such an approach (even if some methods may be inapplicable for a given stratum) has methodological significance for comparison of different methods of quantitative paleohydraulic reconstructions.

Symbols and definitions

C_D – drag coefficient
D – distance between source and deposition sites
d_{av} – average dimension of gravel
d_{max} – maximum particle diameter (b-axis largest clasts)
d_{84} – particle diameter than which 84% of the bed material is finer.
e_b – Bagnold coefficient
f – the friction factor
G – specific gravity
g – acceleration due to gravity
ΔH – difference between altitudes of source and deposition sites.
h – flow depth in the direction of water flow
L – the length of a stratum being deposited
n – roughness coefficient
Q – total sediment discharge
q – specific sediment discharge
Re – Reynolds Number
S – slope of paleoflow.
T – thickness of stratum
t – time required to fill a basin or stratum
u_* – shear velocity
V – depth-averaged flow velocity
VOL – volume of sedimentary body
W – the width of a stratum being deposited perpendicular to water flow direction
w – flow width

τ_c – critical shear stress, (N/m^2)
τ_o – boundary shear stress
θ – dimensionless shear stress
ρ_m – density of mixture
γ_p – specific weight of the particles
γ_f – specific weight of the fluid
δ – standard deviation
ω – fall velocity

Non-Newtonian flow models

According to the data from Table 3, the hyperconcentrated flow model may be most appropriate to the lower member. For this study, the most reliable hydraulic variable is the maximum particle size for these subdivisions of the Demerdji Formation (Table 4). The maximum-size particles probably yield minimum estimates of flow competence, because usually only a small part of the sedimentary body is accessible for research. Other hydraulic variables are less certain.

Table 4. ESTIMATED CRITICAL SHEAR STRESS (NM^{-2}) BASED ON A MAXIMUM PARTICLE SIZES IN DEMERDJI FORMATION

	d_{max} (m)	Highway Research Board data [8]	Baker & Ritter [3]
MSC	0.78	682	601
CSC	0.37	323	198
GS	0.20	175	79

Lord and Kehew [16] based their calculations for determination of paleoflow conditions of glacial-lake outburst deposits in southeastern Saskatchewan and North Dakota on the Shield's criterion for critical shear stress (τ_c) required for particle entrainment. Inasmuch as Shield's work was limited to well sorted (poorly graded) sands in 1 m flows and does not apply to fine sediments or coarse sediments, it is not appropriate for calculation of paleohydrology of Demerdji Formation. Therefore I used an empirical equation, on the basis of data complied by Baker and Ritter [3], determined by Williams [28]:

$$\tau_c = 0.03\, d_{max}^{\,1.49} \qquad (1)$$

Critical shear stress was determined for maximum particle sizes (d_{max}). In addition, τ_c also was estimated using data of Highway Research Board [8]. Both methods provide congruous results (Table 4).

Flow depth was calculated by DuBoys equation, which can be expressed as:

$$h = \tau_c / (\gamma_f S) \qquad (2)$$

Specific weight for the particles is 2.65 x 10^4 N/m^3. Inasmuch as sediment-water mixtures appear to maintain Newtonian behavior up to 20-30% of volume concentration (depending on clay content) [19], the specific weight of the fluid (volume sediment concentration 30%) γ_f = 1.51 x 10^4 N/m^3 was taken into calculation.

Calculation of paleoslope was based on the thickness of the formation (the difference in elevation between the source and deposition sites is minimal) and proposed distance between source and deposition sites. According to investigations of Dobrovolskaya and Snegireva [7], exotic pebbles of various metamorphic schists may be carried from paleoabruptions of Proterozoic basement (descended now and overlapped by sedimentary strata) 100 km to the north from present-day Demerdji Formation locations. Dobrovolskaya [6] proposed that biotite-hornblende-feldspar granite, granodiorite, rhyolite and granitic porphyry pebbles and cobbles had a source in the Ukraine Shield – Proterozoic and Archaean crystalline massif 400 km north of the Crimean mountain ridges. Percentage and roundness of exotics confirm a similar distance of transport. We suppose no relative vertical motions between depositional and source sites. The assumed difference in elevation between the source and deposition sites was used in the calculations taking into account gradual filling of the sedimentation basin. Two sets of the calculated paleoslopes are shown for every member displayed in Table 5. These are the most conservative values for paleoslope estimation. Later tectonic movements made significant changes to the geomorphologic characteristics of the territory. Whereas sources of clastic material either had moderate uplift (as the Ukraine Shield) or were plunged and overlapped by sediments (as Proterozoic basement of the Crimean Plain), deposition area (sedimentary basin of Demerdji Formation) was uplifted by as much as 1.5 km.

Table 5. ESTIMATED PALEOSLOPE (*S*) BASED ON PROPOSED DISTANCE FROM THE SOURCE OF MATERIAL (*D*) AND MINIMUM DIFFERENCE BETWEEN ALTITUDES OF SOURCE AND DEPOSITION SITES (*ΔH*)

	D (km)	*ΔH* (km)	*S* (*ΔH/D*)
MSC	400	0.75	0.0019
	100	0.75	0.0075
CSC	400	0.45	0.0011
	100	0.45	0.0045
GS	400	0.20	0.0005
	100	0.20	0.0020

Average velocity was estimated from Manning's equation:

$$V = S^{1/2} h^{2/3} n^{-1} \qquad (3)$$

The value of n was calculated using an equation developed by Limerinos [15] for the resistance at the particle boundary:

$$n = \frac{0.113\, h^{1/6}}{1.16 + 2 \log (h / d_{84})} \qquad (4)$$

d_{84} was measured to be approximately 0.1 m for MSC (lower member), 0.08 for CSC (middle member) and 0.02 for GS (upper member). Calculated n's are 0.032 - 0.042, 0.031 - 0.039 and 0.025 - 0.029 respectively. The value of n is not sensitive to the changes of other parameters. Variation of n under extreme variations of other parameters does not exceed 30%.

Specific discharge (q in $m^3/s/m$) is determined from the above equations by multiplying depth by velocity. Total discharge (Q in m^3/s) is determined by multiplying q by flow width (w). There are no evidences of channel or bajada deposition: neither small, discontinuous stream terraces, nor channel structures nor rapid lateral facies changes are observed in the entire conglomerate sequence. On the contrary, the conglomerates are laterally extensive, continuous and rather monotonous, showing slight development of laterally continuous stratification. No obvious evidence of the channel edge is observed laterally. Inasmuch as continuous tracing of individual conglomerate beds is no more than 1 km, we assume the value w = 1 km as a conservative estimate of the flow width. Visible extent of conglomerates perpendicular to flow direction (W) is approximately 80 km. Volumes of sedimentary bodies (VOL) are calculated as the product of the length of the member strata in the direction of water flow (L), the width of the member strata athwart of water flow direction (W) and thickness of the member (T). We took into account visible (minimal) parameters of sedimentary bodies. Thus, values of the volumes are underestimated. At the same time it is compensated by very conservative estimation of the flow width. Finally, time required to fill the volume of the member's strata is determined by division of volume of the member to total discharge. All of the estimates resulting from the above calculations are summarized in Table 6.

Table 6. NON-NEWTONIAN PALEOHYDRAULIC CALCULATION OF DISCHARGES FOR DEMERDJI FORMATION, BASED ON THEORETICAL DERIVED VALUES OF τ_c SHOWN IN THE TABLE 4

	τ_c (N/m^2)	h (m)	V (m/s)	q ($m^3/s/m$)	Q (m^3/s) x 10^5	t (days)
MSC	S=0.0019 VOL= 4.8 x 10^{11} (m^3)					
	682	24.1	11.1	268.4	2.68	21
	601	21.2	10.3	217.8	2.18	26
	S=0.0075 VOL= 4.8 x 10^{11} (m^3)					
	682	6.0	8.9	53.5	0.53	104
	601	5.3	8.1	43.2	0.43	109
CSC	S=0.0011 VOL= 4.0 x 10^{11} (m^3)					
	323	19.0	7.7	145.5	1.45	32
	198	11.6	5.6	64.7	0.65	72
	S=0.0045 VOL= 4.0 x 10^{11} (m^3)					
	323	4.8	6.1	29.0	0.29	160
	198	2.9	4.3	12.6	0.13	367
GS	S=0.0005 VOL= 3.2 x 10^{11} (m^3)					
	175	23.2	6.9	160.9	1.61	23
	79	10.5	4.2	44.3	0.44	84
	S=0.002 VOL= 3.2 x 10^{11} (m^3)					
	175	5.8	5.8	33.6	0.34	110
	79	2.6	3.5	9.0	0.09	409

Newtonian flow model

There are many methods for estimation of hydraulic parameters in Newtonian flow model. Chezy's, Manning's, and several similar equations are in common use in open channels. Strictly speaking, these equations describe relationships under conditions of steady, uniform flow. Although, most river channels create conditions of nonuniform flow, these equations can be used without substantial error [5, 22].

Various methods for estimating τ_c from particle size have been developed. Klevberg and Oard [10] applied the methods of Costa [5] and Williams [27] to Cypress Hills and Flaxville sediments to obtain various values of minimum current speed and bed shear stress. Inasmuch as parameters of Crimean conglomerates (the middle unit in particular) are similar to those described by Klevberg and Oard, their methods were applied to the Demerdji Formation.

The minimum shear stress is determined from the maximum particle size using an arithmetical mean of the methods of Baker and Ritter [3] and Costa [5] as modified by Williams [27]. Having solving equation (5) for *h*:

$$h = \tau_c / (\gamma_f \sin \alpha) \qquad (5)$$

where $\sin \alpha \approx S$ from Table 5. The friction factor can be calculated from the Keulegan Equation [4, p. 476]:

$$f = (2.03 \log (12.2h/d))^2 \qquad (6)$$

The magnitude of the mean velocity is calculated from the Chezy Equation:

$$V = (8ghS/f)^{0.5} \qquad (7)$$

Having obtained flow depth and mean current speed, unit discharge can be estimated. From this, total discharge and time required to produce the sedimentary volume are calculated as in Table 6. The results of the Newtonian flow model are summarized in Table 7.

Table 7. PALEOHYDRAULIC COMPETENCE ESTIMATES ASSUMING NEWTONIAN FLUID TRANSPORT AS BED LOAD

	d_{max} (m)	τ_{min} (N/m^2) [1]	S	h_{min} (m) [2]	f	V_{min} (m/s) [3]	q ($m^3/s/m$)	Q (m^3/s) x 10^5	VOL (m^3) x 10^{11}	t (days)	Re x10^8 [4]
MSC	0.78	655	0.0075	8.7	0.053	9.8	86	0.86	4.8	65	2.59
			0.0019	34.9	0.032	12.6	440	4.40		13	13.32
CSC	0.37	218	0.0045	4.8	0.050	5.9	28	0.28	4.0	163	0.85
			0.0011	19.4	0.031	7.4	144	1.44		32	4.38
GS	0.20	95	0.0020	4.8	0.040	4.3	20	0.20	3.2	181	0.63
			0.0005	19.0	0.026	5.4	102	1.02		36	3.09

[1] Minimum shear stress in Newtons per square meter based on maximum particle size
[2] Minimum depth in meters to produce steady flow at minimum shear stress
[3] Minimum mean current speed in meters per second calculated using Keulegan and Chezy equations.
[4] Reynolds Number: $Re < 2 \times x10^3$ =laminar flow; $Re > 10^4$ = turbulent flow

Bagnold's method

Inasmuch as the upper member contains a significant amount of both pebbles and heterogranular sand and silt, Bagnold's method of modeling both traction and suspension is applicable [2, 9]. In this method, the total sediment discharge (q_t) is calculated as the sum of bed (q_b) and suspended (q_s) load:

$$q_t = q_b + q_s = \frac{\tau_o V}{G-1} \left(e_b - 0.01 \frac{V}{\omega}\right) \qquad (8)$$

where $0.2 < e_b < 0.3$.

Equation (8) is applicable for fully turbulent flows, and results are the best for large transport rates [9, p. 214]. As $Re \gg 10^4$ for all subdivisions (Table 7), we consider the flow as fully turbulent.

Boundary shear stress is determined from density of mixture and shear velocity [9]:

$$\tau_o = \rho_m u_*^2 \qquad (9)$$

Sediment concentration of hyperconcentrations range from 5% to 60% by volume [9, p.187]. Mixture density for 5% volume sediment concentration and a particle density of 2650 kg/m^3 is 1085 kg/m^3. Shear velocity is obtained from Julien [9, Table 7.1, p. 118]. The shear velocities that correspond to maximum particle diameters for Demerdji Formation (0.78 m, 0.37 m and 0.20 m) were estimated by simple interpolation of the tabular data. The calculated stresses (τ_o) are presented in Table 8.

Table 8. ESTIMATED BOUNDARY SHEAR STRESS (Nm^{-2}) BASED ON A MAXIMUM PARTICLE SIZES IN DEMERDJI FORMATION, USING EQUATION (9) FOR NEWTONIAN FLUID FLOW

	d_{max} (m)	u_* (shear velocity, m/s)	ρ_m [1] (kg/m^3)	τ_o (boundary shear stress, N/m^2)
MSC	0.78	0.72	1085	562
CSC	0.37	0.56	1085	340
GS	0.20	0.40	1085	174

[1] Density of mixture that contains 5% sediments of specific gravity 2650 kg/m^3.

Boundary *V* values are taken from Table 6. This spectrum of values contains also values of *V* (Table 7) that were obtained with Chezy Equation for the Newtonian fluid flow.

Fall velocity for the mixture is obtained as [9, p.75]:

$$\omega = [(4/3)((\gamma_p - \gamma_f)/\rho_m)(d_{max}/C_D)]^{1.2} \quad (10)$$

The drag coefficient (C_D) for Reynolds number >100 (d>1 mm) is approximately constant. For gravel particles, $C_D \approx 1.5$ [9, p.74]. Specific weight for the particles γ_p is 2.65 x 10^4 N/m^3, specific weight for the fluid (volume sediment concentration 5%) γ_f is 1.08 x 10^4 N/m^3. The density of the mixture is 1085 kg/m^3. The time required to deposit known volume of the member's strata varies from 5 to 35 days as shown in Table 9.

Table 9. PALEOHYDRAULIC CALCULATION OF DISCHARGES FOR DEMERDJI FORMATION, BASED ON BAGNOLD'S METHOD OF NEWTONIAN FLUID FLOW

	d_{max} (m)	τ_o (N/m^2)	ω (m/s)	V[1] (m/s)	q (t) ($m^3/s/m$)	Q (m^3/s) x 10^5	t (days)
MSC	e = 0.3 G-1 = 1.65 VOL = 4.8 x 10^{11} (m^3)						
	0.78	562	15.9	11.1	1109	11.09	5
				8.1	814	8.14	7
CSC	e = 0.3 G-1 = 1.65 VOL = 4.0 x 10^{11} (m^3)						
	0.37	340	6.5	7.7	458	4.58	10
				4.3	260	2.60	18
GS	e = 0.3 G-1 = 1.65 VOL = 3.2 x 10^{11} (m^3)						
	0.20	174	3.1	6.9	202	2.02	18
				3.5	106	1.06	35

[1] Boundary values of *V* from Table 6.

Table 10 summarizes the calculation for all three models.

Table 10. SUMMARY OF THE CONSERVATIVE DATA OF TIME REQUIRED TO FILL AVAILABLE VOLUME OF SUBDIVISIONS OF DEMERDJI FORMATION FOR BOUNDARY VALUES OF CRITICAL SHEAR STRESS AND SLOPE (S) (IN DAYS)

	Non-Newtonian flow model after [16].	Newtonian flow model after [10]	Bagnold's Newtonian flow model from [9]
MSC	21-109	13 – 65	5 – 7
CSC	32-367	32 – 163	10 – 18
GS	23-409	36 – 181	18 – 35

Shading indicates which data are obtained by the method perceived as most appropriate for the given member.

Interpretation of paleohydraulic calculation

The calculated discharges are not typical for observed recent processes – even catastrophic ones. It is possible to compare them with the catastrophic mudflows of 1921 and 1977 in the city Alma-Ata (capital of Kazakhstan Republic) [29].

In July 1921 a mud-rock flow generated by rain carried inside the limits of the city over 3 million m^3 of mud-rock mass. The total volume of the flow together with water was 10 million m^3. Maximal discharge of the flow as recorded in the mountains was up to 5000 m^3/s. As the sediment concentration was about 20 – 25% and width of the valley 500 m, specific sediment discharge was about 3 m^3/s per meter of channel width.

As a result of a breakthrough from a moraine-dammed lake on the Kumbilsu River in August 1977, the Bolshaya Alma-Atinka River had to let through its channel an abnormal mud-rock flow during only one month with the total volume of up to 6 million m^3. The maximal discharge of the flow was registered at 11,000 m^3/s. Some individual mud waves in the mountain part of the river canyon reached the height of 12 m, the splashes at sharp turns of the channel were up to 15-50 m. Mud-rock waves moved with the speed of up to 8-10 m/s and carried stones up to 5-6 m in diameter. In total, the mud-rock flows in this place carried out about 4.2 million m^3 of sediments. In this case specific sediment discharge was not more than 6 - 8 m^3/s per meter of channel width.

Using the most appropriate calculation method for each member of the Demerdji Formation, specific sediment discharge for paleoflow that formed Demerdji Formation was three to thirty times more (Tables 6, 7 and 9) than one of the most catastrophic discharges observed on the territory of the former Soviet Union. Moreover, total sediment discharge for the paleoflow and total volume of sediments (approximately 4×10^{11} m^3 for every member) are also significantly (two orders of magnitude) larger than modern analogues of such facies.

Due to the large specific discharge, the times required to deposit the observed volume of the Demerdji Formation are much smaller than attributed to these strata in the standard time scale (Table 10). Only the lowermost values of critical shear stress and maximum values of slope result in deposition time in years. The most appropriate values suggest deposition times in months to days. Because of uncertainties at every step in the calculation, values in Table 10 should be considered order of magnitude calculations only. Even at this, these values are consistent with the Biblical Flood and a contradictory to the slow-and-gradual, uniformitarian doctrine.

CONCLUSION

Mathematical analysis shows that the paleohydraulic conditions during the deposition of Demerdji Formation were distinct from any modern episodes of catastrophic sedimentation. Hydraulic parameters for both Newtonian and non-Newtonian flow models were calculated for all three members of Demerdji Formation. This procedure reduces the possibility of error and ensures a better assignment of the sediment transport mode. Very significant differences (sometimes up to 250 times – see Table 10) result from calculations by different methods. In spite of this, all models suggest that these strata were formed during very short (in the geological scale) and intensive sedimentation episodes. The final results are consistent with the Biblical Flood and contrary to the standard geological time scale.

Estimations of specific sediment discharge exceeded the same parameter in catastrophic mudflows observed in Middle Asian region in the twentieth century by a factor of three to thirty times. Total calculated deposition times range from 1 month to somewhat more than two year. Using the most appropriate model for each unit, deposition time ranges from 2 to 10 months.

Modern sedimentology, in numerous cases, cannot reject the facts of rapid deposition of observed sedimentary strata. For example, well-known Russian sedimentologist S.I. Romanovski [21] wrote that the geological annals fix short intervals of activity divided by considerably longer intervals of inactivity. "However, not having opportunity to give even approximate estimations of time of breaks of sedimentation, the geologists are compelled to shut their eyes to this problem" [21, p. 22]. He also notes that sometimes the actual time of deposition is only 0.0001% of the assigned evolutionary stratigraphic time span [21, p. 25]. In short, sedimentologists can observe results of catastrophic sedimentation, but necessity of long intervals follows from old Earth dogmas.

No evidence of long interruption on sedimentation is observed in the Demerdji Formation; therefore, we have reason to assume that sedimentation of all Demerdji Formation strata was one integral depositional event. Therefore, calculated deposition time is approximately equal to the total time of deposition time span between beginning and ending of sedimentation of these strata.

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