Quantitative estimation of massflows of subsurface waters in the Earth's crust and hydrogeochemical balance of the Earth's surface

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Massflows of natural waters appearing under the influence of the Earth's gravitation field, Sun heat impact and heatflow from the Earth are realized constantly during development processes in atmosphere, hydrosphere and lithosphere.

Natural water circulation includes several cycles begining with those of short duration between atmosphere and hydrosphere and up to long-term cycles including deep horizons of the Earth Crust. Nowadays so called climatic circulation of natural waters is mostly well investigated. It includes evaporation from the ocean and conintental surface, steam include into the atmosphere, steam condensation and precipitation, surface and subsurface run- off. Lithogenic cycle of natural water circula- tion means the buring of ocean and sea wateralong with sediment in sedimentation process, during thire immersion into the Earth Crust thickness in the process of sedimentary basins evolution and their discharge in a free condition under the changing of system thermodynamic parameters.

Quantitative evaluation of mass flow of different natural water types participating in lithogenic circulation is based on water dynamic process in the frames of separate earth Crust blocks and water reservoirs. Such evaluation is characterized by the development process in time commensurable with the period of its realization (Timofeev, Kholodov, Zverev, 1988; Zverev, 1993). Results of this estimation, shown in Table 1, allow to define relative role of separate massflow of subsurface waters in lithogenic cycle in which linked waters become free physically and chemically on the stages of hypergenesis, diagenesis, catagenesis, metagenesis and metamorphism.

The geological cycle is of great importance in the process of Earth evolution. Connected with convect flow in the upper earth mantle and lithosphere plates drift containing mantle substance raising to surface interact with sea water in the frames middle- ocean mountain ridges creating serpentinous rocks, transported in the drift process of lithosphere plates to deep water grooves where water containing rocks sink into the upper mantle and their dehydrotation begins following with an appearence of part of water on the surface through volcanic apparatuses.

The geological cycle of natural water circulation is formed by the two massflows which have a great importance, they are: the hydrothermal discharge in the limits of rift valleys of middle-oceanic ridges which is developed practically along the whole distance (60000 km) and where the hydrotation of mantle substance is realised and hydrothermal activity in the limits of island arcs and active periferia of continents some part of water in which is formed by the dehydrotation of the main magma and sedimentary rocks. Water amount linked as a result of hydrotation of the main rocks and received by their dehydrotation (0.39×10^{15} g/year) is estimated according to the mass of chemically linked water in the 2nd and 3rd layers of ocean crust and maximum period of its existance (200 m.a.).

Hydrothermal discharge in the limits of island arcs and continent periferia consists of: dehydrotation of sedimentary rocks of the first seismic layers (0.39×10^{15} g/year) and serpentinized rocks of the 2nd and 3rd layers of the oceanic crust (0.41×10^{15} g/year) in a process of their plunging during subduction and raising up stream of subsurface water of meteor origin.

The results of quantitative estimation of modern natural water circulation (Table 1) demonstrates among the main mass flows of natural water the dominant role belongs to waters participating in a climate cycle of the circulation. Their mass move than 4 orders exceeds the streams participating in lythogeneous cycle and 5 orders - in geological. The exclusion is hydrothermal discharge of the middle-ocean ridges which is one of the main constituents of the geological cycle and 2 orders less than subsurface flow.

Hydrochemical balance of the continental mass flows consists of atmospheric, subsurface and proper surface components the main of which is subsurface outflow that is realized both into rivers and directly into sea through a coast line. Small part belongs to atmospheric precipitations and the rest - to surface

TABLE 1. Constituents of modern natural water circulation

Cycle of natural water circulation	Main massflow of natural water	Constituents massflows	Water mass participated in circulation g/year	
Climatic	Atmospheric		119×10^{18}	
	Surface	Atmospheric	44.7×10^{18}	
		Subsurface	44.7×10^{18}	7.9×10^{18}
		Surface proper		36.8×10^{18}
	Subsurface		2.2×10^{18}	
Lithogeneous	Down flow	Water absorption in sediments accumulation process	7.4×10^{15}	
	Up flow	Water discharge in lithogenesis process	4.42×10^{15}	
	Water transportation in linked conditions in hypergenesis		2.7×10^{15}	
Geological	Down flow	Down flow of middle oceans ridges	0.18×10^{18}	
		Linkage in sedimentary processes	0.42×10^{15}	
		Basic rocks hydrotation	0.39×10^{15}	
		Up flow of hydrotherm of middle ocean ridges	$\sim 0.18 \times 10^{18}$	
	Up flow	Dehydation of ocean crust	4×10^{18}	0.39×10^{15}
		Dehydation of sedimentary rocks		0.42×10^{15}
		Infiltration component		3.19×10^{15}

TABLE 2. Massflows of chemical elements in main natural waters types, 10^{14} g/year

Elements of mass flow	With atmospheric precipitations	With surface runoff	Components: Constituents of surface runoff			Accumulation of salts	With subsurface runoff
			atmospheric	subsurface	surface		
K^+	0.35	1.02	0.13	0.15	0.74	0.073	0.1
Na^+	2.36	2.82	0.88	1.1	0.85	0.703	1.0
Ca^{2+}	0.11	6.70	0.04	2.06	4.6	0.563	0.96
Mg^+	0.32	1.83	0.12	0.66	1.05	0.240	0.41
Cl^-	4.51	3.48	1.69	0.65	1.14	0.826	1.03
SO_4^{2-}	0.69	5.01	0.25	0.94	3.82	1.341	1.65
HCO_3^-	0.14	26.1	0.05	10.43	15.62	1.366	3.83
SiO_2	–	5.86	–	1.21	4.65	0.106	0.38
Total outflow of chemical elements							
	8.46	52.82	3.16	17.2	32.46	–5.218	9.36
Mass of water 10^{18} g/year							
	119	44.7	44.7	7.9	36.8	0.41	2.2

constituent. Global hydrogeochemical balance considers chemical elements which together with subsurface waters get into basins without runoff where in a result of intensive evaporation they are realized into processes of continental salinization the intensity of which are estimated by negative magnitudes some elements balance (Table 2).

In general, equation of hydrochemical balance may be presented as follows:

$$Q_{iu} = Q_{subs} + Q_{surf} + Q_{atm} - Q_{acc},$$

where Q_{iu} - complete ionic outflow, Q_{subs} - subsurface ionic outflow, Q_{surf} - surface ionic outflow of surface origin, Q_{atm} - atmospheric component of ionic outflow, Q_{acc} - accumulation of salts in surface horizons of regions without permanent runoff.

The mass of soluble salts involved in lithogeneous circulation (1.75×10^{14} g/year) more than one order less than the redistribution of analogous ones with surface waters. And at last it 2 orders less than the mass of salts participating in geological circulation which is complicated by 2 mass-flow of hydrotherm having a great geological importance: middle-oceanic ridges and islands arcs and active outskirts of the continents. The first one is close to the surface mass flow and the second one is rather small and equal to the common mass flow of the geological cycle.