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Geothermal resources of sedimentary basins in the Republic of Kazakhstan

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ABSTRACT

In Kazakhstan one can distinguish two **types** of formation, containing aquifers: hydrogeological massifs and artesian basins. They differ by physical, geographical, hydrogeological and geological structural conditions. The major part **of** geothermal resources is associated with sedimentary basins which cover nearly 60% of Kazakhstan territory.

In the Mesozoic-Cenozoicdeposits of these basins at depths from 200 to 5000 m (the latter is assumed as a technically accessible depth) drill holes penetrated several aquifers. They **are** of different areal extent, occurrence, depth and thickness. Their temperature varies from 20 to 100.

The map of geothermal resources (1:5 000 000) was drawn for the Kazakhstan sedimentary basins (Fig.1). By the method of development of geothermal resources five temperature zones of aquifers (T^0<20, 20-40, 40-60, 60-90 and >90^{0}C) were distinguished in Kazakhstan. To do this work, maps were drawn to indicate the distribution of temperatures in the Earth's crust in Kazakhstan at the depths of 1, 2 and 5 km and an average depth of isotherms of 20, 40, 60 and 90 ^{0}C for each sedimentary basin.

Geothermal resources of these temperatures zones were estimated by using **of** their areal extent, average temperatures, thickness of aquifers, coefficient of temperature recovery and conductive heat flow from the surrounding rocks.

The temperatures **zones** of sedimentary basins have different potentials. The largest part of resources is associated with the zones where T>90^{0}C ($1356 \cdot 10^9$ toe) and the smallest part corresponds to the zones where T<20^{0}C ($281 \cdot 10^9$ toe).

On the whole the energy potential of a technically accessible and ecologically clean alternative energy source of the Kazakhstan sedimentary basins totals 4.1 trillion toe.

Evaluation and mapping of the Kazakhstan geothermal resources indicates that the republic's **fuel** and power industry could be significantly supplemented and diversified in favor of non-traditional energy source as are geothermal resources.

KEYWORDS

Geothermal resources, maps, temperature zones, energy potential.

The characteristic of thermal needs of Kazakhstan

In Kazakhstan the physical-geographic, geological structural and hydrodynamics conditions determine two types of formation of aquifers: hydrogeological massifs and artesian basins. Aquifers of the hydrogeological massifs are mainly of a local development and correspond to tectonic zones. Due to this fact we did not evaluate the geothermal resources of hydrogeological massifs.

The main geothermal resources are associated with artesian sedimentary basins which cover nearly 60% of the Kazakhstan territory. In the Mesozoic-Cenozoic deposits of those basins at the depths from 200 to 5000 m (assumed technically accessible depth) drill holes penetrated several aquifers, having the temperatures from <20 to >100^{0}C are of different areal extent, occurrence, depth and thickness.

Evaluation of the geothermal resources (BOGUSLAVSKY 1981 and 1997) is based on geothermal parameters: temperatures at the depths from 1 to 5 km, geothermal gradient in sedimentary rocks, temperature of intermediate layer and the thickness of water-saturated basin or its part. These basic data were obtained through systematization, generalization and interpretation of the results from publications and temperature measurements that had been made by drilling and service companies.

Types of utilization of geothermal resources are determined by a heat carrier (fluids) and requirements (power capacity) of consumers. Domestic and foreign researches proposed the different classifications. A study of heat loads in industry, agriculture and district heating enables to combine them in five groups (BOGUSLAVSKY 1984) (table 1).

Group 1 (up to 20^{0}C) – local heat supply for individual consumers (schools, hospitals, private residences, cottages etc.) by using of heat pumps.

Group 2 (20-60^{0}C) – the heat supply for groups of consumers by using of heat pumps; green-houses; hot-water supply for industry; agriculture and residential areas; fish-farming; recreation facilities and balneology; heat supply for mining and construction purposes (thawing of frozen **rocks;** chemical and bacterial leaching etc.).

Group 3 (60-90^{0}C) – heat supply for industry or residential areas by using of either peak heating/thermotransformation or low temperature heaters; heat supply for medium temperature processes including mining operations (geothermodynamics treatment of oil formation etc.).

Group 4 (90-150^{0}C) – heat supply for industry and residential areas with partial peak heating or thermotransformationby using of conventional heaters; heating and heat supply for high temperature processes (steaming of ferro-concrete structures; chemical, pulp and paper, woodworking, food and many other industries), local heat and power supply for factories, villages in remote areas; electricity generation by using of low boiling heat carriers or on a pair **of** low parameters.

Group 5 (>150^{0}C) –electricity generation by turbines using with a direct steam-water cycle.

Table 1: Consumers of geothermal energy, divided into groups.

Groups of consumers	Heat carri	T^{0}C	Heat load, GJ/h
	Name of group	T^{0}C	
	Extremely low T^0	<20	0,01-0,50
	Low T^0	20-60	0,5-50,0
	Medium T^0	60-90	50-500
4	High T^0	90-150	500-5000
5	Extremely high T^0	>150	>5000

Geological-geothermalconditions

The data, obtained from the sedimentary basins were used to drawn map of the Kazakhstan geothermal resources (table 1). Five temperature zones were distinguished in the Kazakhstan aquifers (T<20, 20-40, 40-60, 60-90 and >90^{0}C). To evaluate their geothermal resources maps were drawn to show the distribution of temperatures in the Earth's crust in Kazakhstan at the depths of 1 , 2 and 5 km and an average depth of isotherms of 20, 40, 60 and 90^{0}C for each sedimentary basin. Colors clearly mark the concentration of geothermal resources in temperature zones.

The determination of thickness **of** water-saturated formations was based on the geological data from investigation of the Mesozoic-Cenozoic regional geological-structural elements (figure 1), identification of territories with similar lithological and facies conditions of sedimentation which enabled to find the sequences of sediments with an identical composition in individual basins as well as in structure tectonic zones on the whole. For those territories the geological columns of different parts of the basins were studied in order to have a ratio between the thickness of certain column complexes and thickness of water-saturated rocks in them. The fact that this approach to determine an aquifer thickness is correct, can be testified by a similar work previously done for the Callovian deposits in South Manguyshlak.

In the basins under discussion the thickness of aquifers totals 30-60% of an average thickness of lithological and facies complexes with variations in some cases from 10 to 90%. Within the above mentioned temperature zones it is estimated on the water-saturated portion of the reservoirs that are located in those zones.

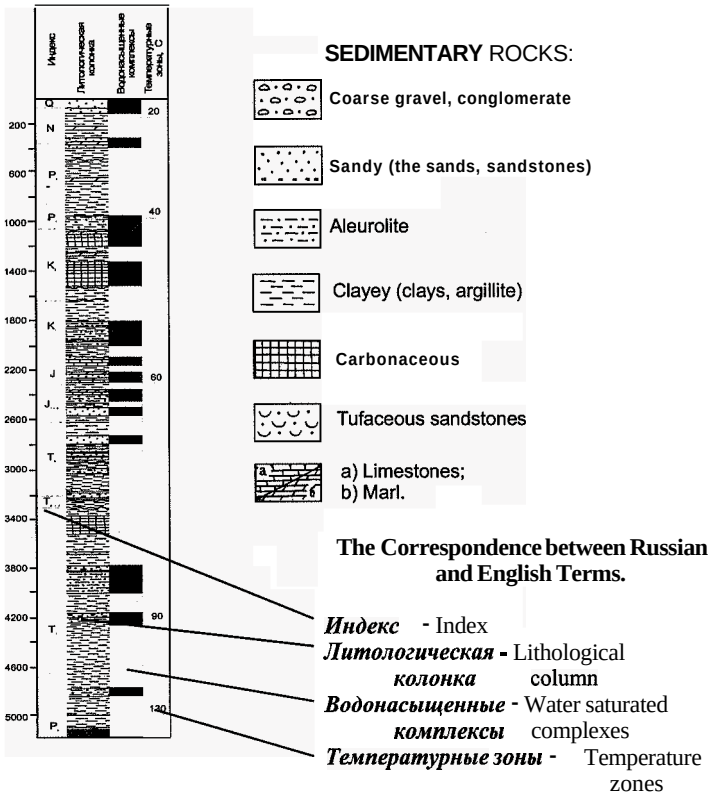

Figure 1: The sedimentary column of Prikaspian basin.

Forecasted geothermal resources

Geothermal resources of each temperature zone were estimated by using of specially developed methods (BOGUSLAVSKY 1981 and 1997), taking into account the areal extent and average temperature of the zone, thickness of water-saturated complexes, coefficients of temperature recovery and conductive heat flow from the upper/lower deposits and ambient temperature.

Regarding the Mesozoic-Cenozoic sedimentary basins the zone with $T<20^0C$ prevails over 60% of the Kazakhstan. Its thickness varies from 140 to 820 m. An aquifer thickness varies from 30-450 m (the lower boundary is in the Neogene-Paleogene and Quaternary deposits and it reaches the Cretaceous and Jurassic on the basin margins). Geothermal resources of the zone are estimated at $280,7 \cdot 10^9$ toe (table 2).

Table 2: Density of geothermal resources of the Kazakhstan sedimentary basins, toe/m^2.

	Sedimentary basins	Temperature zones (^{0}C)					Total
		<20	20-40	40-60	60-90	>90	
I	Prikaspiy	0,27	0,15	1,75	1,26	1,4	4,83
II	Ustyurt-Buzashin	0,02	0,11	0,63	3,22	7,49	11,47
III	Manguyshlak	0,04	0,10	0,31	3,36	8,47	12,28
IV	Aral	0,03	0,21	1,35	4,34	0,60	6,53
V	Syr-Daria	0,18	0,41	0,52	0,52	1,01	2,64
VI	South-Torgay	0,33	1,27	1,14	0,48	-	3,22
VII	North-Torgay	0,22	0,18	-	-	-	0,40
VIII	North- Kazakhstan	0,11	0,39	-	-	-	0,50
IX	Teniz	0,09	-	-	-	-	0,09
X	Shu-Sarysuy	0,16	0,61	1,17	1,87	2,04	5,85
XI	West-Iliy	0,16	0,27	0,52	6,56	2,03	9,54
XII	East-Iliy	0,15	0,58	1,37	4,62	7,77	14,49
XIII	Balkhash	0,26	0,75	0,61	-	-	1,62
XIV	Alakol	0,13	0,82	1,34	-	-	2,29
XV	Zaisan	0,03	1,01	1,28	-	-	2,32
XVI	Priirtysh	0,02	0,24	0,80	1,04	1,86	3,96
	AVERAGE	0,14	0,47	0,98	2,73	3,63	7,95

The next temperature zone (20-40^{0}C) is less extended. It does not occur in the marginal parts of the basins. The zone thickness is from 150 to 950 m. The aquifer thickness is 80-450 m. The zone does not have any specific stratigraphic correspondence. It is observed in the Neogene-Paleogene, Cretaceous and Jurassic deposits. Geothermal resources of the zone total $332,2 \cdot 10^9$ toe. The unit potential is 0,10-1,01 (average – 0.47) toelm' throughout the basins (table 2).

The zone with T=40-60^{0}C is not observed in all basins. It is not present in the North Torgay, North Kazakhstan and Teniz basins. The zone thickness varies from 450 to 955 **m** and an aquifer thickness is 180-580 m. The zone contains the Paleogene and Cretaceous deposits. Its geothermal resources total $903,3 \cdot 10^9$ toe. The unit potential **is** within 0,52-1,75 toelm' (table 2).

The zone with T=60-90^{0}C is not observed in all basins either. It is not present in the North Torgay, North Kazakhstan, Teniz, Balkhash, Alakol and Zaisan basins. The zone thickness significantly increases in the Prikaspiy, Aral, Shu-Sarysuy, West Iliy and East Iliy basins were it reaches 1400 m. The temperature zone is mainly located in the Cretaceous and Jurassic. Geothermal resources of the zone total $1239,0 \cdot 10^9$ tons of toe. Its unit potential is 0,48-6,56 toe/m^2.

The zone with T>90^{0}C is located in the Prikaspy, Ustyurt-Buzashin, Manguyshlak, Syr-Daria, Sbu-Sarysuy, West and East Iliy basins. The zone thickness varies from 100 to 3000 m, temperature T attains 160^{0}C. The base of the zone reaches 5000 m which is conditioned by the maximum depth that we assumed for evaluation of geothermal resources. Geothermal resources of the zone is equal to $1356,6 \cdot 10^9$ toe. Its unit potential is 0,60-8,47 toe/m^2.

On the whole the energy potential of a technically accessible and ecologically clean alternative energy source of the Kazakhstan basins amounts to 4,2 trillion toe. Distribution of geothermal resources in temperature zones of sedimentary basins is not even. Resources with T>90^{0}C are more frequent ($1356,6 \cdot 10^9$ toe) than the ones with T<20^{0}C ($280,7 \cdot 10^9$ toe).

According to a comparative estimate of the potential of the rocks under discussion the Kazakhstan sedimentary basins can be divided into four types.

1. Basins with a unit potential (UP) of <1 toe/m^2: Teniz, North Kazakhstan, North Torgay sedimentary basins. They occupy 19% of the area of all sedimentary basins;
2. Basins with UP=1-4 toelm': Zaisan, Alakol, Balkhash, **Priirtysh,** Syr-Daria, South Torgay basins – 29% of the territory;
3. Basins with UP=4-7 toe/m^2: Prikaspiy, Aral, Sbu-Sarysuy masins – 41% of the square of area;
4. Basins with UP=9-15 toelm': Ustyurt-Buzashin, Manguyshlak, West and East Iliy basins – 1 1% of area.

The geothermal resources were presented and evaluated according to the administrative region of Kazakhstan so that investors and district administrations could know and use this

Table 3: Forecasted technically accessible geothermal resources of administrative regions of Kazakhstan.

	Administrat. regions	Temperature zones, T^{0}C										Total
		S	Q	S	Q	S	Q	S	Q	S	Q	Q
1	Uralsk	150	38	150	28	150	248	149	222	141	238	774
2	Atiirausk	118	32	63	9	112	175	107	135	96	122	473
3	Aktausk	158	6	158	13	153	82	137	457	113	887	1445
4	Aktubinsk	211	48	125	33	212	192	96	196	49	42	511
5	Kiiziilordiinsk	154	25	148	75	87	75	50	97	17	5	277
6	Rostanai	155	36	19	19	6	6	-	-	-	-	61
7	Kooshetausk	60	7	24	8	-	-	-	-	-	-	15
8	Akmolinsk	50	5	-	-	-	-	-	-	-	-	5
9	Jeskagon	110	26	33	22	14	15	3	1	-	-	64
10	Shimkent	110	19	86	39	66	34	53	28	28	28	148
11	Torask	86	14	34	21	7	8	5	10	1	2	55
12	Almata	92	20	45	27	21	28	10	62	4	26	163
13	Pavlodar	99	2	99	24	44	35	31	32	4	7	100
14	Semipalatinsk	49	3	17	16	3	4	-	-	-	-	23
	IN TOTAL	1602	281	1001	334	875	902	641	1240	453	1357	4114

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information. The map of geothermal resources shows their boundaries, total predicted potential and values according to the temperature zones.

Table 3 gives the distribution of forecasted geothermal resources of Kazakhstan sedimentary basins by administrative regions. For the whole republic they total $4211{,}5 \cdot 10^9$ toe including $3304{,}4 \cdot 10^9$ toe for the western regions (77,3%), $640{,}2 \cdot 10^9$ toe for the southern regions (15,6%), $243{,}9 \cdot 10^9$ toe for the central and northern regions (6%). $23{,}0 \cdot 10^9$ toe for the eastern regions.

Evaluation and mapping of the Kazakhstan geothermal resources indicated that the republic's fuel and power industry could be significantly supplemented and diversified at the expense of a non-traditional energy source: the heat of the Earth's Interior. The Map of Geothermal Resources of Kazakhstan characterizes the level of heat of its subsurface environment and helps to estimate a real potential of natural resources for the heating and power industry (figure 2 and table 4). Also together with other maps of Atlas it is a basic factual element to evaluate the technological, ecological and other conditions for exploitation of subsurface resources in Kazakhstan.

Uralsk - Уральская	**Prikaspy - Прикаспийский**
Aktausk - Атыраузская	Ustyrsko-
Aktuhinsk - Актюбинск	**Buzashinsky - Устюрско-Бузашинский**
Kiiziilordiinsk - Кызылординская	**Mangyshlak - Мангышлакский**
Kostanai - Костанайская	**Aral - Аральский**
Akmolinsk - Акмолинская	**North-Torgay - Северо-Торгайский**
Kooshetausk - Кушетауская	**South-Torgay - Южно-Торгайский**
Shimkent - Шимкентская	Syrdariinsky - Сырьдарьинский
Torask - Торассаан	**North-Kazakhstan - Северо-Казахстанский**
Almata - Алматынская	**Teniz - Тенизский**
Pavlodar - Павлодарская	West-Iliisky - **Западно-Илийский**
Semipalatinsk - Семипалатинская	East-Iliisky - Восточно-Илийский
Shu-Sarysuisky - *Шу-Сарысуйский*	Alakol - **Алаколъский**
Priirtysh - Прииртышский	**Zaisan - Зайсанский**
Balhash - Балхашский	

Table 4: Correspondance between English and Russian names of sedimentary basins.

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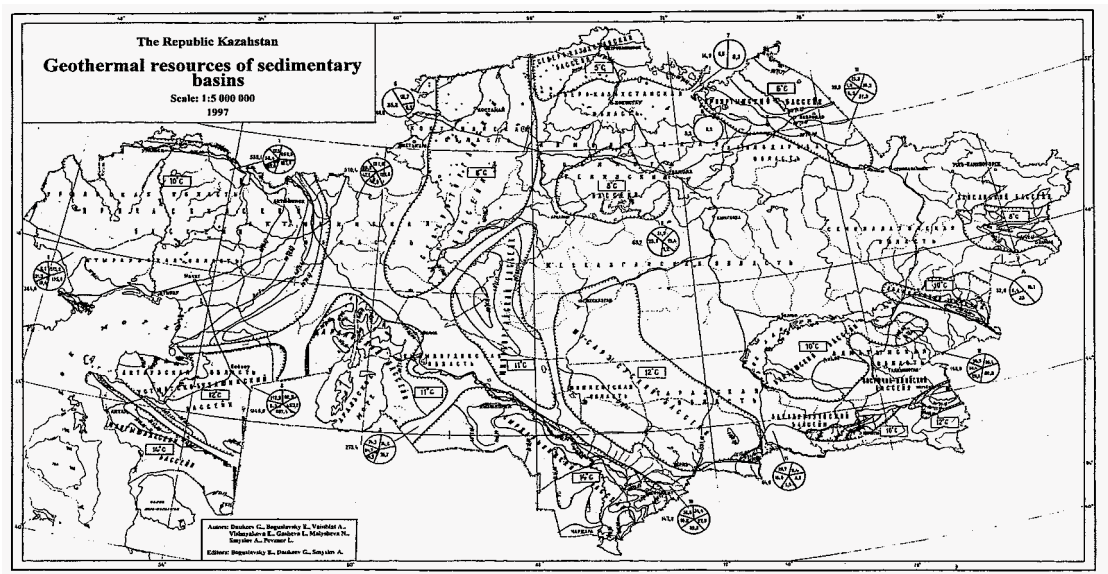

Figure 2: Map of geothermal resources of Kazakhstan