EXPLORATION OF TEMPERATURE FIELD AND EVALUATION OF GEOTHERMAL RESOURCES OF THE PRECASPIAN DEPRESSION

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ABSTRACT

Heat flow density of the Precaspian Depression increases from North to South and from East to West. The regional thermal background is normal. Lateral and vertical variations of heat-flow density are explained by many factors. One of the most important characteristic features of the Precaspian Depression is the existance of a salt layer- Thermomechanical modelliny shows that the salt layer and the salt diapirs are the positive factors of the formation and preservation of oil and gas generation zones and location of high temperature water. Thermomechanical modelliny give5 the possibility to locate the miyration of the oil window during the process of sedimentary basin evolution and evaluate the geothermal resources of the basin. Variations of heat-flow density are explained by the characteristics of layers and the history of the basin evolution-

1. INTRODUCTION

For evaluation of geothermal resources of the basin it is necessary to investigate its temperature field, calculate natural water resources of every complex, to know the areas and effective thicknesses of different waterbearing complexes, to explore the specific water discharge of rocks. The most difficult question here is the investiyation of temperature field. Although there are many boreholes due to high oil-gas potential of the Precaspian Depression, the problem is far from its final decision. For geothermal field reconstruction it is necessary to use borehole data together with elements of modelliny, especially because of salt diapirs and high thickness of sedimentary cover. The thermomechanical simulation of sedimentary basins evolution in connection with geothermal field reconstruction is very important as independent problem. The most perspective regions for yeothermal resources using could be analysed by construction of the map of isotherm +50 oC depths.

2. DESCRIPTION OF THE MODEL

Numerous yeoloyical structures are characterized by rather gentle occurence of layers and significant elevation of horizontal regional scale L over the vertical scale h of the tipical thickness. This allows to introduce a small parameter h/L into the analysis of the problem. The second small parameter of the problem F/R, F - the Frude number, R - the Reynolds number, arises while analysing the rheological behaviour of matter in the layers.

Slow lithospheric deformation will he simulated by models of viscous flow in a multilayerd, incompressible, high viscosity Newtonian fluid, using the Navier-Stocks equations (Zanemonetz et al.,1974), (Svalova, 1992, 1993).

Let us consider the rheological behaiour of a multilayered continuous medium, whose parameters (viscosity, density and thermal conductivity) vary from layer to layer. The movement in each layer is defined by the Navier-Stocks equation and the equation of continuity.

By expanding the velocities U, V, W, pressure P and boundary equation in series of powers of small parameter we can obtain the equations of layers boundaries in the zero approximation depending on the boundary morpholoyy of the layers foot and its velocity field (Zanemonetz et al., 1974).

Let us consider the evolution of the geological structures related to the approach of the mantle diapir to the layers lower boundary. In this case from the analysis of the obtained relationships, we may infer existence of a critical depth of the asthenosphere uplift defininy the morpholoyy of the basement surface (Svalova, 1992,1993).

If the diapir is not deep or the velocity of diapir rise is large, then day surface is convex and reflects the morphology of the diapir.

If the diapir is deep and upwelling is slow a depression is formed at the Earth's surface- And it is possible that stretching in lavers is not larye.

In case of restriction existiny for the lateral extension above the ascending diapir it follows from the detailed analysis of the boundary morpholoyy that there exist two critical depths of the mantle diapir that control the reconsruction of the movements above it. When the lithosphere is thin the boundary is convex at the center, i.e. it repeats the diapir morpholoyy, while its marginal parts are concave which is caused by the convergence of lateral boundaries. For thick lithosphere the centre of structure is downwarped while its marginal parts are uplifted. This reyime is conceivably responsible for the sedimentary basin formation- An intermediate regime is characterized by surficial movement reconstruction (Svalova,1993).

The surface elevation above the diapir depends on its velocity and depth. The regional yeodynamics is controlled by the rheology of layers and depends on whether the layers have time for diffluence above the mantle or the velocity of the uprise prevails over the diffluence. This analysis of the dynamics of a layered lithosphere above a risiny mantle diapir shows that if the diapir is deep and its velocity is low, a depression is formed on the Earth surface. If the velocity of rising diapir is high or the diapir is not deep a surface bulge can be formed. The comparison of the theoretical sections with geological reconstruction for Alpine belt sedimentary basins shows good conformity (Svalova,1993).

It is possible to connect all stages of evolution of the Precaspian Depression with up-

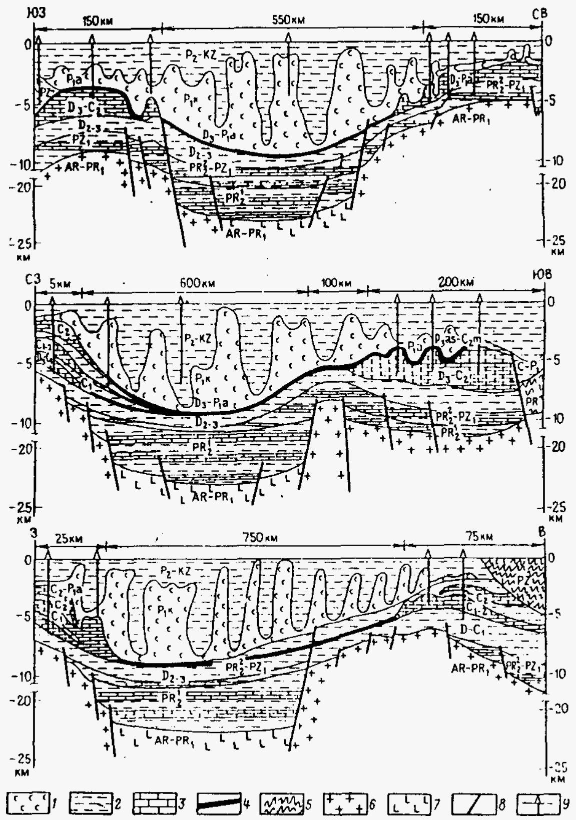

Figure1 .Geoloyical section of the Precaspian depression.

rocks: **1** - salts, 2 - terrigeneous, 3 - carbonates, 4-clays, 5-condensated, complexes: 6 - granitic, 7 - basalts; ***8*** - faults, 9 - deep boreholes-

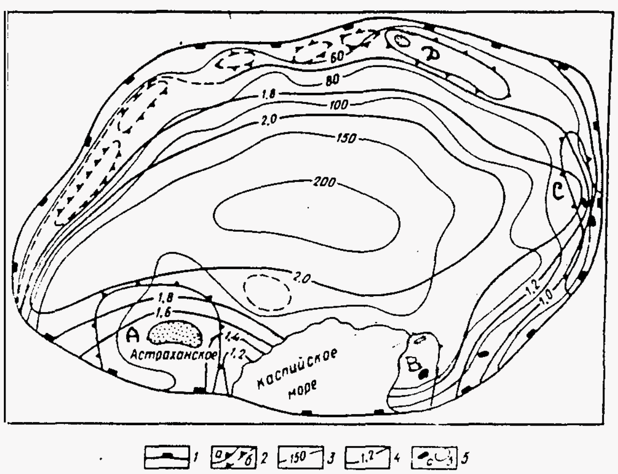

Figure 2. Scheme of the thermal-pressure conditions of subsalt deposits of the Precaspian Depression.

Boundaries:
1 - of the Precaspian oil-gas potential province,
2 - of the oil-gas potential zones(a - known, b - forecasted);
3 - the seoisotherms on the subsalt deposits surface, **C**;
4 - the isolines of anormal layer pressure coefficients;
5 - oil /a/ and **gas** /b/ deposits.
Main oil-gas deposits:
A - Astrahan, A - Tenriz, **C** - Kenkijak, D - Karachaganak.

welliny of mantle diapir (Soloviev et **al.,1991).**

The Frecaspian Depression is **a** unique structure of ancient platforms with sedimentary cover near 24 km. The existence of mantle diapir could he confirmed by geophysical data,that fix two gravity maximum (Hobdinsky and Aralsorsky), the complex of higher electroconductivity at the depth of 70-100 km and hiyher deep heat flow in the center of structime.

The morpholoyy of basement and Moho is characteristic for upwelling movements from deep mantle (Fig.1, Maksimov et al., **1990),** (Fig.2, Aksenov et **al.,1985).**

The upwelling of mantle diapir in early riphej could he the reason of triangle rift in basement - Pachelmsky, Novoalekseevsky and Safpinsky - on the stage of swell formation. The stare of deep syncline formation in Precaspian Depression is connected with reyime of slow upwelling. More detailed information about sedimentary cover structure rives possibility to reconstruct more complicated picture of the structure evolution.

3. GEOTHERMY OF SEDIMENTARY BASINS

In the history of the Earth's evolution we have rather **quick** episodes (3-4 **MY)** of development of the geological structures and long periods (30-40 MY) of stable development. For short space of time in this sense the velocities of matter found from mechanical equations are **substituted** to the heat conductivity equation. Temperature and heat flow are continuous at the boundaries **,** T = O oC at the day surface, T = 1200 oC at the lithosphere **-** asthenosphere boundary. Analysis of decision shows that surface yrad T depends on the history of evolution and thickness of sedimentary cover (Svalova, 1993).

The temperature of hasement surface depends on thickness of sedimentary cover and it is not isotherm. The analysis shows that for deep sedimentary basins the shape of possihle oil-gas generation zones **is** concave in upper part of the basin and it is convex in deep part if deposits exist. In deep basins the possihle zones of **oil-gas** yeneration are situated in peritherical parts of structure. In nondeep basins the deposits zones are formed in central part, that rives rood ayreement with geological data. During the hasin evolution the deposits zones arise in the central part, spread to the boundaries, destroy in the centre and stay in peripherical parts of the basin only. It could be a case of Precaspian Depression (Svalova, 1993).

Convective movements help to temperature changing in the lithosphere. Sinking of the matter above the risiny diapir on the stare of the deep depression formation can explain the low surface heat flow in Black sea and South Caspian Pepression at the same time with high thickness of sedimentary cover.

Let us analyse some features of the geothermal field of the Precaspian Depression- The reyional geothermal background is normal. Heat-flow density increases from North to South and from East to West. Surface heat flow is 25-33 mW/mxm in the Worth-East part and 50 mW/mxm near the Caspian 5ea (Fig.3, Gordienko and Zavgorodnjaja, 1985), Table 1.

Table 1. The main geothermal zones of the Precaspian Depression.

ZONE (Fig.2)	T oC **5** km depth	∇ T oC /100m
KENKIJAK	76-90	1,7-2,0
CASPIAN	**162-186**	**2,8-3,1**
TENGI**Z**	160-167	**2,8-3,2**
ASTRAHAN	124-156	**3,0-3,6**

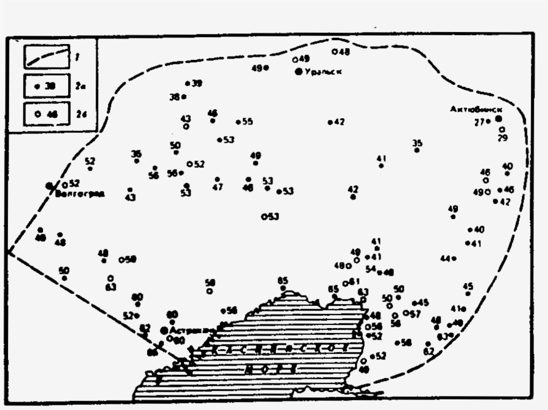

Figure 3. Heat flow for the Precaspian Depression, mW/mxm.

1 - boundaries of the Precaspian Depression,
2 - points of heat flow determination:
a - separate, b - groups.

Reconstruction of paleotemperatures by vitrinite reflectance for Easten part of depression shows that the temperatures was **110-125** oC at the depth of **3.7-4.5** km, that is 40-50 oC higher than mordern temperatures.

For the analysis of the yeothermal field chanyinys let **us** consider temperature distribution for stable staye of evolution.

Analysis of results shows that the smaller lithosphere thickness the larger surface heat flow. Maximum suface heat flow will be in the centre of depression above the mantle diapir. The yeothermal data confirm it very well. Increase of sedimentary cover thickness h influences on decrease of surface heat flow q very much. It explain ayain the low heat flow of Black sea and South Caspian Depression.

Every new staye of the diapir upwelling is characterized by smaller lithosphere thickness, but laryer sedimentary cover thickness. It means that temperatures of oil-gas yeneration are achieved on smaller depth. The migration of oil window up the section takes place with any new episode of sink and sedimentation. New layers of sedimentary cover are involved to the process of oil-gas generation (Svalova et al., 1993).

Very important factor of temperature calculatiny for many sedimentary basins is the existence of salt layer. Investiyation of subsalt complex for Precaspian Depression is especially important a5 for yiyantic oil and gas deposits there.

Let us consider three-layer sedimentary cover consistiny of above-salt complex, salt complex and sub-salt complex with basement temperature T **(X,Y,t).** Then we can find the relationships between **grad** T in layers. Larger yrad T will be in above-salt layer and sub-salt layer. There is low yrad T in salt layer. Hence hiyher temperatures are achieved on smaller depth in above-salt layer when salt layer exists. It means that in such basins the main phase of oil yeneration is on smaller depth. And in sub-salt layer the temperature decreases quicker up the section, that preserves the deposits in upper part of sub-salt complex. Hence the salt layer is the important positive factor of oil and **gas** generation and preservation zones.

The salt diapirs chanye the surface heat flow in lateral. If the salt layer has thickening up the section then the heat flow increases above the diapir. And heat flow increases in sub-salt layer under the salt diapir too. Hence the salt diapirs are the local positive factors for deposits formation.

If at any staye of basin evolution the heat yeneration begins in the layer doe to exogenic chemical reaction, for example, it chanyes the temperatures in the sedimentary cover. Let there is the heat yeneration in the middle layer and there is no heat generation in layers above and below. The analysis shows that existiny of the layer with heat yeneration increases the heat flow above the layer and decreases the heat flow under the layer. Temperature chanyiny in the layer has the parabolic character.

Hence the local increase of the surface heat flow is possible as due to layer of hiyher heat conductivity as due to heat generation in the layer. Rut influence of these two factors on underlying layers will be different.

Salt domes and powerful salt complex complicats the regional picture **of** temperature distribution **especially** in sooth-eastern part of the Depression, where salt layer is not deep (100 - 500 m). Above salt diapir the temperature is 3-5oC higher than in moulds on the same depth. For deeper horizons there are yeothermal "depressions" in the salt diapirs as compared with surrounding terrigeneous complexes. Chanyiny of temperature for **500-1000** m depth is **10-21** oC. In western part of Depression the salt domes are deeper (1500-2000 m) and their influence is smaller, Table 2 (Bochkareva et al., 1973). All these data are well explained by yeothermal modelling.

Table 2. Temperature distribution for 500-1000 m depths in salt domes structures for eastern and western parts of the Precaspian Depression.

depth, m	East T oC	West T oC
500	21.2-31.9	23.4-28.4
750	27.0-42.1	37.3-43.0
1000	31.5-52.4	51.4-56.0

4. GEOTHERMAL AND WATER RESOURCES OF THE PRECASPIAN DEPRESSION

Sedimentary rocks of the Precaspian Depression contain numerous horizons of underyroand waters. Fresh and law salting waters, suitable for water-supply, are formed in upper horizons and in boundary settiny territories. High salt waters and brines are wide spread in the central part and low horizons.

Structure of the Precaspian Depression with complicated system of salt domes defines the different conditions of spreading, supply and movements of underground waters. There are more than 1000 salt domes in the Depression.

Discharye direction is from boundaries to the centre of the basin in above salt waterbearing complexes. Local flow is to the local discharye structures.

Discharye of underground waters is spread in all area of the basin. The main structures of discharye are regional faults and river valleys, Caspian sea and **numerous** fractures around salt domes. For subsalt complexes the main area of discharge is South-Emben uplift and zones of reyional faults in boundary and central parts of Depression. Discharye is also by vertical internal miyration in between domes zones.

Velocity of deep waters for all waterbeariny complexes decreases from supply areas **(Ural - Mugodzhar)** to the centre of Depression and decreases from upper to low complexes. The chanyiny **is** from **8-14** m/year to **0-0.2** m/year in lateral direction for upper complexes, from 1.1 m/year to 0.1 m/year in lateral direction for complexes of different depth (Kandagach station, Bochkarjova et al., 1973).

There are two strongly different hydrogeological complexes in the Precaspian basin - above-salt and subsalt ones. Underyround waters of subsalt complex have mineralization of 320-450 g/l. For this reason and because of high depth (5-6 km) they could not be used for power-and-heat supply.

Geothermal waters of the Low-Cretaceous and Middle-Jurassic complexes of above-salt horizons have the most practical interest. A salinity is 0.1- 1.0 g/l in areas of intensive water exchange- In deeper complexes it is higher, up 50-150 g/l and more (Muhamedzhanov, 1990).

Borehole data (Muhamedzhanov, 1990, Gordienko et al., *1985)* together with modelliny (Svalova, 1993) give possibility to evaluate geothermal resources of above-salt complexes of **the** Precaspian Depression. The main results are shown in the **Table 3**.

The most perspective regions for geothermal resources rising are the areas with small depth of isotherm +50 oC in the south-west part of Depression and the settiny reyion to the south-east from Depression. Not-deep thermal water, high pressure and large discharge from wells (10-15 l/sec.), not high mineralization (Muhamedzhanov, 1790) and huge resources give yood possibility for geothermal water using in national economy.

CONCLUSIONS

1. Mechanical-mathematical modelling shows that structure of depression is formed on the Earth's surface above rising mantle diapir if diapir is deep and its velocity is low- Stretching in layers can be not large.

2. If the velocity of rising diapir is high or the diapir is not deep **the** structure of superficial swell can be formed-

7. For every case it is possible to find critical parameters of the problem connecting form of the diapir, its depth and velocity with structure of the Earth's surface.

Table 3. Geothermal resources of above-salt complexes of the Precaspian Depression.

Temperature limits and middle, oC.	Area, 10xx6 mxm	Middle thickness, m	Specific water loss	Water resources, 10xx9 mxx3	Heat resources 10xx12 kcal	10xx6 t condi-tionel fuel
Low-Cretaceous waterbearing complex						
20-40, 30	75812.5	50	0.15	568.594	17057.82	2496.89
40-75, 57	341781.2	45	0.10	1538.015	87666.85	12523.83
75-100, 87	31875	50	0.15	239.062	20798.39	2971.19
Jurassic waterbeariny complex						
20-40, 30	115250	60	0.12	829.8	24894.0	3556.29
40-75, 57	204437	50	0:12	1226.6	69916.2	9988.02
75-100, 87	81437	60	0.12	586.3	51008.1	7286.87
> 100, 105	20906	60	0.12	150.5	15802.5	2257.50
					Common:	41020.47

Borehole data and results of modelling could be well reflected on the map of depth5 of isotherm 50 oC, that gives possibility to Investigate the geothermal resources of the basin. (Fig.4).(Bochkarjova et al., 1973).

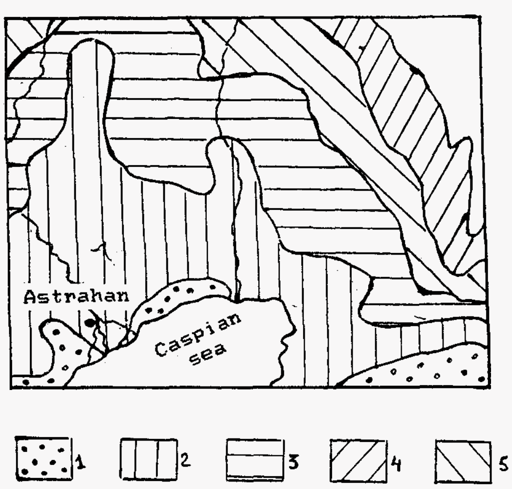

Figure 4. Depth of isotherm +50 oC.

1 - < 1000 m, 2 - 1000-1500 m,
3 - 1500-2000 m, 4 - 2000-2500 m,
5 - > 2500 m.

4. Thermomechanical modelliny shows that surface yrad T depends on the the basin evolution history and thickness of sedimentary cover.

5. During the basin evolution the oil-gas generation zones arise in the central part, spread to the boundaries, are destroyed in the center and stay in the peritherical parts of the basin only- It yives yood ayreement with yeoloyical data.

6. Low heat flow of the Black sea and South Caspian Depression can be explained by high thickness of the sedimentary cover and by sinking of the lithosphere matter above upwelling mantle diapir.

7. The layer of hiyher heat yeneration in the sedimentary cover increases the heat flow above and decreases under the layer.

8. The layer of hiyher heat conductivity in the sedimentary cover increases the heat flow above and under the layer. The salt layer and the salt diapirs are the positive factors of the formation and preservation of oil and gas yeneration zones and location of high temperature water.

9. Thermomechanical modelliny gives the possibility to evaluate the geothermal resources of the basin.

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