

ARTICLE

Rings Structures on Ice Lake Baikal

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ABSTRACT

On the cosmic picture of the ice surface lake Baikal discovered a dark ring a diameter of 7-8 km. The author shall give a physical interpretation of the given phenomenon, having expected that shaping rings are connected with a surge of the warm natural gas from sedimentary a thick mass of the bottom of the Baikal. Convection is formed in thick mass of water in the manner of torah around surge of the natural gas, which carries become warm water before surface (the lower edge ice) side from pole of the natural gas. The mechanism heatconductivity heat gets to the upper edge of the ice, where snow and ice begin intensive to melt. As a result thawed patch is formed on snow-clad ice in the manner of a ring.

1. Background

About 23 years ago, by order of the Ministry of Natural Resources of Russia, daily space monitoring of the Baikal natural territory began with the help of the UniScan receiving station and the EOStation software complex, which operate in Moscow (ScanEx RDC) and Irkutsk (Baikal Center LLC). With the help of these satellite data, unique ring formations with a diameter of 7-8 km were discovered, which are formed on the snow-covered ice field of Lake Baikal (Figure 1). Rings appear one or two at a time, but not every year. Undoubtedly, the formation of rings is not a new phenomenon, and it has occurred in previous years. But without satellite monitoring, it was

impossible to detect them. Although the rings are of considerable size, it is almost impossible to see them from the ice and even from the mountain ranges surrounding the basin of the lake.

Rings on Lake Baikal became famous in April 2009, when they became widely discussed on the internet. The author first observed them on a computer monitor on April 4, 2009, when pictures of the rings were posted on the internet^[1]. I immediately proposed a physical mechanism for the formation of rings, and established a system of equations describing convection. Even earlier, the presence of rings was established by employees of the Limnological Institute, in particular Nikolai Granin. He suggested that the rings may arise due to the rise of deep waters,

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which are caused by eruptions of mud volcanoes. At the same time, in the central part of the future ring structure, the temperature rises (on average by half a degree compared to other parts of the lake), and the so-called anticyclonic current (circular flow directed counterclockwise) is formed. The current enhances vertical water exchange, as a result of which the ice cover is destroyed more strongly over the zones of maximum flow velocities^[2,3]. The dark circles visible in the images are areas with minimal ice thickness. With an average thickness of the ice cover at the southern end of Lake Baikal of 70 centimeters within a radius of two kilometers from the center of the rings, it does not exceed 43 centimeters. Thin ice is more saturated with water than the average for the lake, and this contrast is clearly observed from space. Our consideration clarifies the picture proposed by Nikolai Granin - we abandon the anticyclonic flow as the cause of the formation of rings, and instead of mud volcanoes we consider emissions of natural gas. The latter is due to the fact that after the sinking of the underwater vehicle "Paisis" (<http://nabaimar.ru/baikal/>) in 1977 and 1991, the locations of mud volcanoes became known, the coordinates of which do not coincide with the coordinates of the rings in question.



Figure 1. Circular rings 1 (near the Svyatoy Nos Peninsula) and 2 (near the southern tip of Lake Baikal) on Lake Baikal. Picture from 4.04.2009.

In 2008-2010, MIR underwater vehicles sank to the bottom of Lake Baikal^[4,5]. Studies conducted by scientists were widely covered by the media and the internet. In particular, one of the moments of the descent of one of the devices was shown on television. At the same time, footage of natural gas emissions from the bottom of the lake literally flashed in the form of a clearly visible jet of bubbles against the background of the water column. These shots were shown at night local time, so the author, unfortunately, did not have time to photograph them. But natural gas emissions and their demonstration in a television report undoubtedly took place.

2. Physical Interpretation of Ring Formation

Lake Baikal is geologically a graben lake, a section of the earth's crust bounded by steeply inclined gaps, confined to the rift zone (the Rift is a large linear tectonic structure of the earth's crust, hundreds to thousands of km long). Rifts are characterized by increased heat flow and seismic activity, and direct rift depressions are characterized by a powerful thickness of sedimentary rocks, several kilometers away, where a lot of organic matter accumulates. Increased thermal field and temperature gradient cause intense gas formation^[6]. The release of natural gas, in particular methane, from the bottom of the lake in summer is observed due to bubbles rising to the water's surface and in winter the formation of "proparin" (ice-free surface of the water) with a size of 0.5 m - 100 m across. In addition to such relatively small proparins, space images of Lake Baikal revealed dark rings of an abnormally large size - with a diameter of 7-8 km (Figure 1)^[1]. In April 2009, the rings were discovered west of Cape Lower Headboard of the Svyatoy Nos peninsula (Figure 1, circumference 1) and at the southern tip of Lake Baikal (Figure 1, circumference 2). In Figure 2 and Figure 3 rings are "tied" to the bathymetric map Baikal, where the geographical coordinates of the centers of the rings are also indicated (Bathymetric maps are geographical maps that display the underwater relief using isobaths, supplemented by depth marks). The fact that in the process of formation of rings the determining role is played by heat fluxes can be seen in Figure 4, where it is shown how as a result of heating is disturbed the strength of the ice, and it is crushed into ice blocks of different sizes. I associated the formation of rings on the surface of the ice with the giant convection of the entire water column around the release of natural gas. In the middle part of the rings, the temperature of the subglacial water is higher, according to the observations of Nikolai Granin on the rest of the water. This leads to the melting of snow and the ice itself.

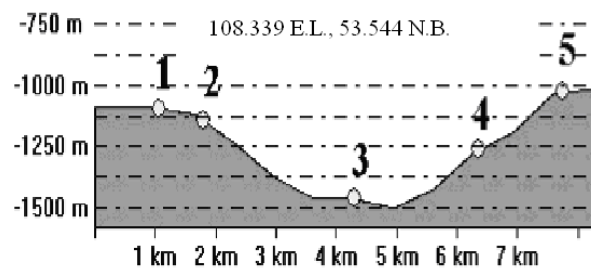


Figure 2. A section of the ring 1 in latitude on the bathymetric map near the Peninsula of the Holy Nose. 1 and 5 are the outer edge of the ring, 2 and 4 are the inner edge of the ring, and 3 are the center of the ring. At the top are the geographical coordinates of the center of the ring.

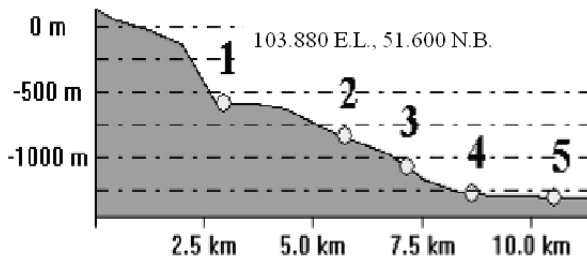


Figure 3. A section of ring 2 in longitude on a bathymetric map near the southern tip of Lake Baikal. The numbers indicate: 1 and 5 - the outer edge of the ring, 2 and 4 - the inner edge of the ring, 3 - the center of the ring. At the top are the geographical coordinates of the center of the ring.



Figure 4. The destruction of the ice field was a result of the warming of the ice near the southern end of Lake Baikal. Photo from the International Space Station “MCS” from 25.04.2009.

The water of Lake Baikal is characterized by the fact that in the spring the temperature throughout the depth practically does not change and is usually $T_0 = 3.2 - 3.4 \text{ }^\circ\text{C}$. Only near the surface, from a depth of 150-200 m, the temperature gradually decreases to almost $0 \text{ }^\circ\text{C}$ afloat. The resulting temperature gradient is so insignificant that water convection does not occur (we are distracted from the internal currents of the water column that are not associated with temperature convection). Already here it can be seen that the problem under consideration is significantly different from the well-known Convection of Benard - Rayleigh. However, the outflow of natural gas from the sedimentary layer of the bottom disrupts the mechanical balance of water. The water column comes into a convective current, which, due to symmetry, takes a shape close to the torus, as shown in Figure 5. Contacting the lower point with warmer natural gas, as a result of the rotation of the water column, heat is carried to the upper point. The following system of equations makes it possible to prove that the temperature distribution on the surface of water in the middle part of the rings has a maximum. This picture is

indicated by a completely similar phenomenon accompanying the explosion of a hydrogen bomb, as in Figure 6. The difference only that the convection we are considering arises from the laminar rise of natural gas, and the convection associated with the explosion of a hydrogen bomb arises from the rise of the turbulent flow of combustible products. (As far as the author knows, foreign researchers call the model in question - the model of the explosion of an atomic bomb). However, in both cases, convection takes the form of a torus. A well-known example of the rotation of smoke rings can be given.

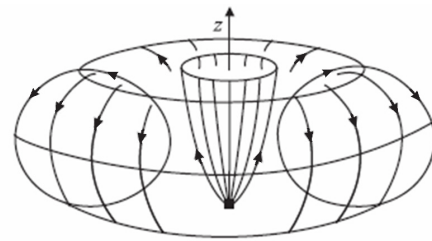


Figure 5. A high-quality picture of the surfacing of a warm jet of natural gas and the convective flow of water around the jet in the form of an oblate torus. A shaded square at the bottom of the upward jet indicates the size of the source.

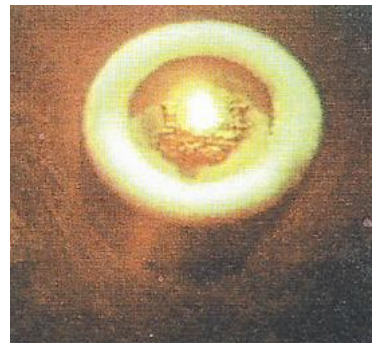


Figure 6. Hydrogen bomb explosion (top view).

3. Convective Flow Equation System

Let us proceed to a theoretical description of the convective flow. Such a description is possible only if we consider the equations of hydrodynamics (navier-Stokes equation and continuity equation) and the thermal conductivity equation together. We'll start with the thermal conductivity equation, which looks like this:

$$\frac{\partial T}{\partial t} + (\vec{v} \cdot \nabla) T = \chi \nabla^2 T. \tag{1}$$

Coefficient χ is called the thermal diffusivity coefficient. Its presence in Equation (1) means that the thermal properties of water are described by only one parameter.

The convection we are considering is a stationary process in which all quantities do not clearly depend on time. For such quantities, the partial derivative in time turns to zero. In the absence of an external heat source, the water mass has a stationary temperature distribution T_0 , depending on the location only. Convection occurs due to the fact that an extraneous source of heat is introduced into the liquid. As a result of a stationary temperature distribution T_0 a small addition of temperature is applied T . It follows that in order to describe convection by Equation (1), the value of T must be replaced by the sum T_0+T . Then Equation (1) will take the following form:

$$(\vec{V} \cdot \nabla) T_0 + (\vec{V} \cdot \nabla) T = \chi \nabla^2 T_0 + \chi \nabla^2 T. \quad (2)$$

Convective flow as a mechanical movement occurs at a slow speed. Therefore, speed V in Equation (2) is a first-order quantity of smallness, as is the small addition of temperature T . Separating quantities of different orders of smallness and neglecting the second-order term, we obtain the following equations:

$$\nabla^2 T_0 = 0. \quad (3)$$

$$(\vec{V} \cdot \nabla) T_0 = \chi \nabla^2 T. \quad (4)$$

Equation (3) for our problem of theoretical description of convection can be immediately solved. For the equilibrium state of water in the Earth's gravitational field, the temperature T_0 may depend only on the depth of z , where the z -axis is directed from the bottom to the water surface (Figure 7). Then Equation (3) has two solutions. One of them corresponds to the constant value of the equilibrium temperature: $T_0 = const$. The second solution will be a linear dependence on depth:

$$T_0 = c - A z, \quad (5)$$

where c and A are constant integrations defined by the condition of the problem. For of the Baikal water column, both cases are realized. Of the Baikal water column, both cases are realized. First, from the bottom of the lake to some depth with an elevation of 150-200 m from the surface of the water, the equilibrium water temperature is constant and is 3.2-3.4 °C.

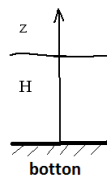


Figure 7. The depth of Lake H , the z -axis is directed from the bottom of the lake to the water's surface.

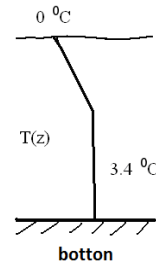


Figure 8. Equilibrium temperature profile of the water mass in the spring on Lake Baikal.

Then the temperature is linearly compared with the temperature of the surface layer of water corresponding to the season. In the month of April, when it is possible to observe rings on Lake Baikal, the temperature of Celsius on the surface is zero (Figure 8). We can see that in the spring the equilibrium temperature decreases evenly, which is why in solution (5) there is a minus sign before the constant A . If we assume that the depth is 1 km, and up to the mark of 800 m from the bottom, the temperature is constant and equal to 3.4 °C, then the solution of Equation (3) can be written as follows:

$$T_0 (^\circ C) = \begin{cases} 3.4, & z = 0 - 800 \text{ m} \\ 17 - \frac{3.4}{200} z, & z = 800 - 1000 \text{ m} \end{cases}$$

Let us now turn to the Navier-Stokes equation:

$$\frac{\partial \vec{V}}{\partial t} + (\vec{V} \cdot \nabla) \vec{V} = -\frac{\nabla P}{\rho} + \nu \nabla^2 \vec{V} + \vec{g}, \quad (6)$$

supplemented by the continuity equation:

$$\nabla \cdot \vec{V} = 0. \quad (7)$$

where ν is viscosity coefficient, g is the acceleration of free fall, P is the pressure, ρ is density of water.

Velocity V is a small velocity of convective water flow, so $(\vec{V} \cdot \nabla) \vec{V}$ as a second-order term of the small can be omitted. In addition, we consider the stationary course. In this case, Equation (6) takes the following form:

$$0 = -\frac{\nabla P}{\rho} + \nu \nabla^2 \vec{V} + \vec{g}. \quad (8)$$

In the absence of an external heat source, the density of water has a constant and equilibrium value ρ_0 . With slight heating, the volume of water increases, respectively, the density decreases. In the first order of approximation of the small addition of temperature T , which is a consequence of the appearance of an external heat source, the addition to the density will be proportional to this temperature T . Thus, the density becomes equal to:

$$\rho = \rho_0 - \beta \rho_0 T. \quad (9)$$

Here is the multiplier β is called the coefficient of thermal expansion. In the range from 0 °C to 3.4 °C it can be considered permanent.

In the pressure, let's highlight the atmospheric pressure P_A on the surface of the water, hydrostatic pressure $-\rho_0 g z$ a column of water, and a small additive P associated with the convective flow. Thus, in Equation (8), the value P is replaced by the following expression:

$$P_A + \rho_0 g (H - z) + P, \tag{10}$$

where H is the depth of the lake. Substituting Equations (9) and (10) into Equation (8), in the first order of approximation by P , V and T we get:

$$0 = -\frac{\nabla P}{\rho_0} + \beta \bar{g} T + \nu \nabla^2 \bar{V}. \tag{11}$$

To eliminate the pressure P , let's use Equation (11) on the left with two rotor operators $\nabla \times (\nabla \times \dots)$. Using the rules of vector analysis, and taking into account the continuity Equation (7), the result is:

$$\nu (\nabla^2)^2 \bar{V} = \beta \nabla (\bar{g} \cdot \nabla T) - \beta \bar{g} \nabla^2 T. \tag{12}$$

We obtained Equations (3), (4), (7) and (12), which, supplemented by boundary conditions, completely determine the spatial distribution of temperature T and velocity \bar{V} convective flow (describe the known "mushroom" formed during an atomic explosion).

4. Surfacing Natural Gas Jets

Convection in the form of a violation of mechanical equilibrium occurs when an external heat source appears. For Rayleigh-Bénard convection, the source of heat is a heated bottom. For the convection we are considering, the source of heat is a jet of heated natural gas introduced into the water column. Its mass element Δm carries the element of heat $\Delta Q = \Delta m C_p T_s$. In here C_p is specific heat of the jet at constant pressure, T_s is temperature measured from the equilibrium temperature of the surrounding water column. Let ρ_s be density of natural gas, and $\rho_s < \rho_0$, so that the jet floats in the form of a pillar with a round cross-section. If r_s is the cross-sectional radius of the jet, Δz_s is the jet height element, then the mass element will be

$$\Delta m = \rho_s \pi \Delta r_s^2 \Delta z_s.$$

During the time Δt natural gas floats to a height $\Delta z_s = V_s \Delta t$, where V_s is the speed of the jet surfacing. Combining all the expressions, we get that in a unit of time a column of natural gas carries heat:

$$\frac{\Delta Q}{\Delta t} = \pi \rho_s C_p T_s V_s r_s^2. \tag{13}$$

Jet surfacing is a regular and stationary process. Ignoring also the dissipation of heat, we come to the position that the expression (13) is a constant value. Thus,

$$T_s V_s r_s^2 = const. \tag{14}$$

Consider the rise of a jet of natural gas in a viscous continuous column of water. Its surfacing is a stationary laminar current. The equation of motion of the jet is derived from the equations of hydrodynamics in a similar way to convective motion and leads to Equation (12), but only with the non-zero left side, and the values provided with the index s :

$$(\bar{V}_s \cdot \nabla) \bar{V}_s = -\nabla \frac{P}{\rho_s} - \beta_s \bar{g} T_s + \nu_s \nabla^2 \bar{V}_s. \tag{15}$$

All the terms of Equation (15) are of the same order, so

$$\frac{V_s^2}{z_s} \sim \beta_s g T_s \sim \nu_s \frac{V_s}{r_s^2}.$$

Solving these equations together with Equation (14), we find that the jet emerges in the form of a figure of rotation with the z -axis, moreover (Zeldovich relations ^[6]):

$$r_s \sim \sqrt{z_s}, V_s = const, T_s \sim \frac{1}{z_s}. \tag{16}$$

Expression (16) will be boundary conditions for the problem of determining the spatial distribution of the temperature of the water column, especially interesting for us the distribution of temperature at the surface. Let's rewrite the last ratio in Equation (16) as follows:

$$T(\sqrt{x^2 + y^2} = r, z = H) \sim \frac{1}{z}. \tag{17}$$

This ratio describes the distribution of temperature in the convective flow at the point of contact with the jet. A laminar jet emerges from the sedimentary stratum of the bottom from a hole of some finite size, the minimum size of which can be found from the expression (14) and conditions $\rho_s V = \max$ ^[7]. Regularity $r_s \sim \sqrt{z_s}$, it is convenient to specify and write in the following form:

$$r_s = \sqrt{D z_s}. \tag{18}$$

Below we define its numerical value for the value of D .

5. Spatial Temperature Distribution

The above system of Equations (3), (4), (7) and Equation (12), describing convection, has not yet received proper mathematical research. But they can be solved in one approximate case. Namely, near the water's surface, we can assume that the convective flow of water is almost parallel to the water's surface. This means that when $z = H$ speed component V_R in the plane xy will have a lot more vertical components V_z . Let's project Equation (12)

onto a plane $x y$:

$$v (\nabla^2)^2 V_R = \beta g \nabla_R \frac{\partial T}{\partial z}, \tag{19}$$

where ∇_R is determined by the ratio $\nabla_R^2 = \frac{\partial^2}{\partial x^2} + \frac{\partial^2}{\partial y^2}$.

Near $z = H$ speed V_R can depend only on the radial in the plane $x y$ of the coordinate r . Then the expression on the left in Equation (19) is a function only of r . In order for Equation (19) and the expression on the right to depend only on r , the temperature T must be a linear function of z . Thus,

$$T(r, z) = u(r) + v(r) z. \tag{20}$$

Since the temperature $T(r, z)$ counted from the value T_0 , which with $z = H$ is zero, then and $T(r, z = H) = 0$. From here it can be seen that the functions $u(r)$ and $v(r)$ have different signs. In addition, at the point of contact of the convective flow with the natural gas jet, when $r = \sqrt{D} z$, the boundary condition Equation (17) must be met. This can be achieved if $T(r, z)$ select the following form^[8]:

$$T(r, z) = a h^2 T_m \left(\frac{1}{r^2} - b \frac{h z}{r^4} \right). \tag{21}$$

Indeed, substituting $r = \sqrt{D} z$, get

$$T(r, z) = T(r, z) = \frac{a H^2 T_m}{D} \left(1 - b \frac{H}{D} \right) \frac{1}{z},$$

in agreement with Equation (17). Permanent a , b and T_m to be determined below.

When writing the solution in the form of Equation (21), we actually followed the general method, when solutions of a system of equations like Equation (7) and Equation (12) are searched in such a way as to satisfy the boundary conditions of the problem. The solution Equation (19) has a remarkable feature – dependence $T(r, z = H)$ has max. It follows that at a point max,

$$R_m = \sqrt{2b} H, \tag{22}$$

and, in addition,

$$a = 4 b. \tag{23}$$

So, for the ring in Figure 2 $R_m = 2.78$ km and $H = 1.46$ km, from where $b = 1.81$ and $a = 7.25$. To establish the meaning of a quantity D in the formula (18), suppose that at the point of contact of water with the jet, the temperature $T_s = 0$ °C (ice and snow do not melt on it). At a point maximum temperature $T_m = 4$ °C (the ice is not melting yet, and the snow has already melted). Then, substituting $r = \sqrt{D} z$ in Equation (21), for D we obtain a quadratic equation whose smallest solution will be:

$$D_m = 4 \text{ km}. \tag{24}$$

We see that the dimensionless quantities a and b have values of the order of one. This circumstance once again justifies the choice of a solution in the form Equation (21). Here are the following values related to the ring in Figure 3:

$R_m = 2.76$ km and $H = 1.05$ km, $b = 3.45$, $a = 13.8$ and $D = 5.17$ km.

They differ significantly from similar values for the values of ring No 1 (Figure 2). This difference seems to be related both to the approximation used in solving Equation (12) and to the difference in bottom relief for both rings.

To obtain other approximate solutions near the middle of the ring, it is necessary to involve the entire set of boundary conditions. However, information on the physical characteristics of the natural gas jet is not yet available. Therefore, scant experimental data (in fact, only space images and a bathymetric map were used) do not yet allow for a more detailed analysis of the phenomenon of the formation of giant rings on ice.

6. Convective Instability

Consider the question of the criterion for the occurrence of instability of the water column in the form of a torus around the release of natural gas from the bottom of Lake Baikal. For the Rayleigh-Bénard convection, a similar question is set out in the book *Theory of Elasticity*^[6]. Let's look for the perturbation of velocity and temperature described by Equations (3), (4), (7) and Equation (12) in exponential form:

$$\exp(i \vec{k} \cdot \vec{r}) = \exp(i k_R r + i k_z z). \tag{25}$$

On the right in the exponent we write $i k_R r$, because we are considering a cylindrically symmetrical case. The appearance of instability will mean the emergence of the root of the equations,

$$\text{Im } k_R (\text{Re}) = 0, \text{Im } k_z (\text{Re}) = 0. \tag{26}$$

Im means taking an imaginary part. The number of Rayleigh Re will be determined below.

Taking into account Equation (25), this system of equations takes the following form:

$$\frac{d^2 T_0}{d z^2} = 0, \tag{27.a}$$

$$-V_z \frac{d T_0}{d z} = \chi k_R^2 T + \chi k_z^2 T, \tag{27.b}$$

$$i k_R V_R + i k_z V_z = 0, \tag{27.c}$$

$$v (k_R^2 + k_z^2)^2 V_R = -\beta g k_R k_z T. \tag{27.d}$$

Here it is advisable to move on to one equation. For

example, excluding speed components V_R and V_z , we get the equation for temperature T :

$$\left[(k_R^2 + k_z^2)^3 - \text{Re } k_R^2 \right] T = 0. \quad (28)$$

And here the number of Rayleigh Re is a dimensional quantity. If the wave number k is measured in units of some length ΔH , then the Number of Relays will be dimensionless:

$$\text{Re} = \frac{\beta g \Delta H^4 (-d T_0 / d z)}{\nu \chi}. \quad (29)$$

It was noted above that at a significant part of the depth the temperature $T_0 = \text{const}$. This means turning the Rayleigh number to zero and no convection. Since convection undoubtedly takes place, a component must be added to the right side, arising from the fact that the water column is not in contact with a solid surface, but with a heated liquid stream of natural gas. In an area where the temperature is linearly dependent on the depth, we have $-d T_0 / d z = A$. Substituting in Equation (28) $k_z^2 = -d^2 / d z^2$, get:

$$\left[\left(\frac{d^2}{d z^2} - k_R^2 \right)^3 + \text{Re } k_R^2 \right] T = 0. \quad (30)$$

This equation formally coincides with the corresponding equation in the book *Theory of Elasticity* [6]. Therefore, you can immediately write the critical values for the Rayleigh number and the radial component of the wave number:

$$\text{Re}_c = 1708, k_{Rc} = 3.12 / \Delta H. \quad (31)$$

Replacing in Equation (28) $k_R^2 = -\frac{1}{r} \frac{\partial}{\partial r} \left(r \frac{\partial}{\partial r} \right)$, get:

$$\left[\left(\frac{1}{r} \frac{\partial}{\partial r} r \frac{\partial}{\partial r} - k_z^2 \right)^3 - \text{Re} \frac{1}{r} \frac{\partial}{\partial r} r \frac{\partial}{\partial r} \right] T = 0. \quad (32)$$

As far as is known, no such equation has been analyses. Such an analysis should give the same value for Re_c , that both the given in Equation (31) and the numerical value for k_{zc} . However, the value for k_{zc} can be found without actually solving Equation (32). Indeed, by substituting Equation (32) with Equation (28), you can immediately find:

$$k_{zc} = 3.97 / \Delta H. \quad (33)$$

Further, since it is obvious that,

$$k_{Rc} \sim 1/R_m, k_{zc} \sim 1/H,$$

then from the ratios (31) and (33), after exclusion ΔH , followed by Equation (22), which, by this, gets another justification. Due to different boundary conditions for our

problem, and for the Rayleigh-Bénard convection, the numerical values in formulas (31) and (33) will generally be different. However, the conclusion about the linear relationship (22) between the radius of the rings and the depth of the lake will remain.

7. Conclusions

It was established that the formation of rings on the ice surface of Lake Baikal is associated with giant convection of the water column due to the release of warm natural gas from the sedimentary bottom of Lake Baikal. Natural gas, rising to the surface, cools, but manages to warm up the surrounding cold water. As a result, convection forms in the water column in the form of a torus around the release of natural gas, which carries warm water to the surface (lower edge of the ice) away from the column of natural gas. By the mechanism of thermal conductivity, the heat reaches the upper edge of the ice, where ice and snow begin to melt intensively. As a result, a protalin in the form of a ring is formed on snow-covered ice. Convection in the form of a torus is described by joint solutions of the equations of hydrodynamics and the equation of thermal conductivity. From these equations, a system of equations describing convection in the form of a torus is obtained. By the mechanism of thermal conductivity, the heat reaches the upper edge of the ice, where ice and snow begin to melt intensively. As a result, a protalin in the form of a ring is formed on snow-covered ice. Convection in the form of a torus is described by joint solutions of the equations of hydrodynamics and the equation of thermal conductivity. From these equations, a system of equations describing convection in the form of a torus is obtained. An approximate solution for the spatial distribution of temperature near the water surface is given. The latter is due to the fact that our system of equations has not yet received proper mathematical research. Indeed, let us recall that about 15 years have passed since the discovery of the Bénard cells and their mathematical description by Rayleigh. The question of convective instability is considered. In solving this question, it was established that the radius of the rings is linearly related to the depth of the lake.

Conflict of Interest

There is no conflict of interest.

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