Deposits of Hydrocarbons with Renewable Reserves and Experience of New Estimation Methods

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***Abstract*—The paper gives a review of the Russian scientists' investigations in the field of research of the hydrocarbon renewal reserves. The conception of two-step formation of hydrocarbon deposits, relied on organic theory of oil origin, is in the base of introduced investigations. The main clauses of the conception are immersion of potentially source rocks to the depth of oil and gas windows, existence of present-day migration canals and presence of accumulation zones. Attention is given to development of prognostic criteria of oil and gas bearing zones with renewable hydrocarbon reserves. Represented investigations confirm the conception of two-step formation of hydrocarbon deposits.**

Keywords—gas window; fault tectonics; oil and gas migration; zone of gas accumulation

I. INTRODUCTION

Being a base of energy sectors in many countries hydrocarbons are considered to be exhaustible resources. Therefore their depletion is one of the global humanity problems. Analysis of global oil production indicates imbalance between hydrocarbons output and growth of their reserves. Nevertheless potential of this branch of industry may be increased using hydrocarbon exploration within new territories and water areas, which are difficult to access, and more detailed investigation of oil and gas bearing old oil and gas producing regions with a bulk of geological information and advanced infrastructure.

Hypotheses of geological history reserves, renewed in the past and modern stage, are advanced lately. They are confirmed by numerous facts and examples such as the Alberta province in Canada, Karakuduk and North Buzachi oilfields in Kazakhstan and other. In Russia the most notable examples are Romashkinskoe oilfield (the Republic of Tatarstan), Starogroznenskoe oilfield (the Republic of Chechnya), a number of hydrocarbon fields in West Siberia Basin and deposits of the Volgograd region. Gavrilov V.P. considers that general characteristics of oil and gas recovery of such fields are pulsating reservoir condition against the background of continuous development [2, 7, 8, 9].

The facts of the renewal reserves are often explained by different modifications of inorganic theory of oil origin that have been developed by the Soviet and then Russians scientists. Dmitrievskij A.N. links the process of the hydrocarbon renewal with the present-day tectonic movement [3, 10]. Reserves of Romashkinskoe oilfield have been estimated several times. In every recalculation the quantity of hydrocarbons increased. Some scientists explain this phenomenon as influence of the fault structure of sedimentary cover and its linkage with crystalline basement. Gavrilov V.P. concluded that hydrocarbons come from different sources – oil is generated by organic matter while hydrocarbon gas may have inorganic nature. Therefore terms "renewal of oil and gas" and "inorganic origin of hydrocarbons" have got synonymic meaning.

However some Russian scientists explain the processes of hydrocarbon reserves renewal from the position of organic theory of oil and gas origin in the form of the conception of staged formation of hydrocarbon deposits. Confirmations of their conception are oil and gas fields of the Volgograd region, The Middle Caspian and the Terek-Caspian Foredeep (Fig. 1).

In 2006 Bochkarev A.V. and Ostrouhov S.B. proposed the model of two-step formation of hydrocarbon deposits. The main clauses of the conception are immersion of potentially source rocks to the depth of gas window, existence of present-day migration canals and presence of accumulation zones. Such zones may be worked-out and developed hydrocarbon deposits.

In the course of the whole geological history the territory of Volgograd left-bank region was being immersed that caused accumulation of large sediment layers. At the second stage the source rocks have appeared in the depth of gas window (depths are 3000-4000 m; catagenesis gradation is MK_3-MK_5). Consequently, a new stage began - the migration of hydrocarbons and penetration into the traps filled with oil at this moment (Fig. 2) [1].

Confirmations of two-step formation conception are the data of fields development. Over a period of the Alekseevskoe oilfield development, the increase of reservoir pressure from 48 MPa to 58 MPa was observed, and, at the same time, the gas-oil ratio grew to 558 m^3/t.

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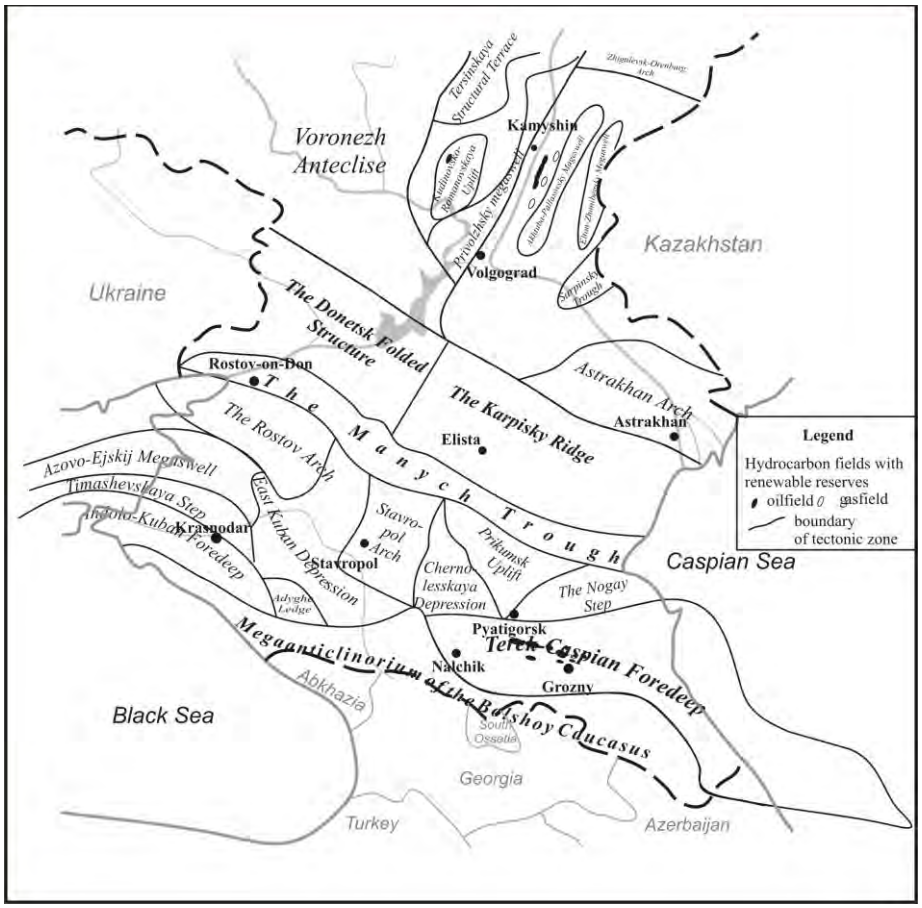

Fig. 1. Tectonic map of the South of Russia with areal of oil-and-gas accumulation with renewable reserves

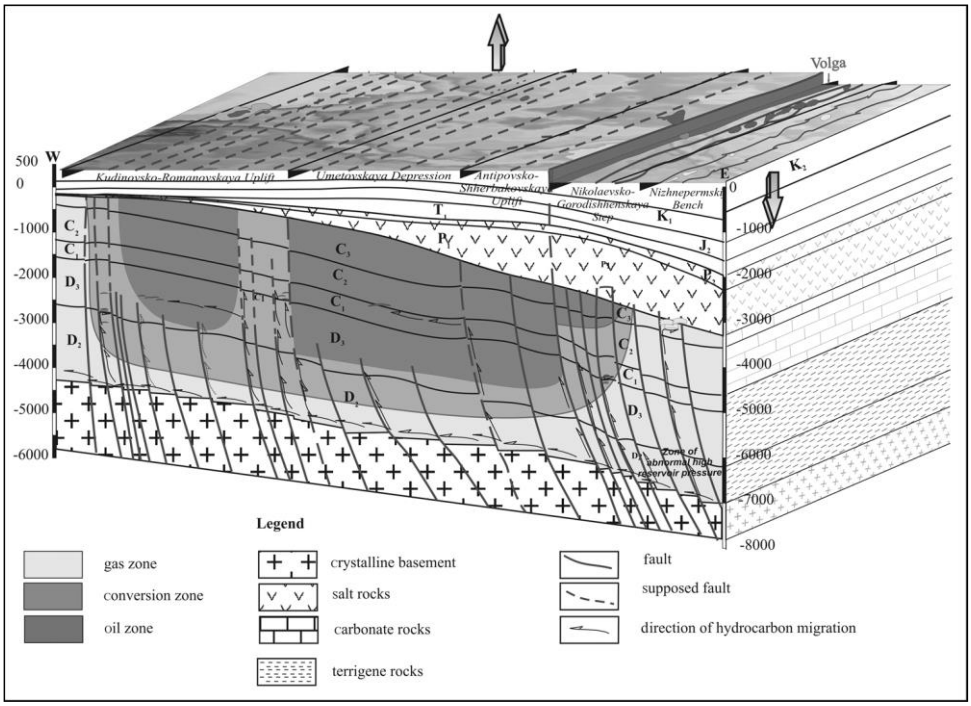

Fig. 2. Scheme of two-step formation of hydrocarbon deposits of Volgograd Region

II. Results and Discussion

Conception of staged hydrocarbon deposit formation and the processes of hydrocarbon reserves renewal can be confirmed by other striking examples such as oilfields of the Republic of Chechnya. The analysis of development of 15 oilfields within the Tersko-Caspian depression was realized by Sianisyan E.S. and Prozorova G.N., researchers of oil and gas department of Southern federal university [4].

By the beginning of military operations in the Republic of Chechnya, a decrease of reservoir pressure and fall of yearly output was observed in all oil deposits of the region. In the wartime, oil output stopped, but during periods of episodic recovery reservoir pressure and rate of oil output were increasing.

A significant example is the Hankala oilfield. Development of this oilfield included maintenance of reservoir pressure, but from 1994 to 2006 these measures were not realized. Since 2006 flow rate has exceeded previous level of this parameter (Fig. 4). During ten years of the war when oil output has uncontrolled character gas-oil ratio had grown very rapidly to 1200 m^3/t. This level of gas-oil ratio is the biggest among all oil deposits within the Tersko-Caspian Foredeep. In addition water cut has decreased to 0 %. It should be noted that the peripheral part of Paleogene deposit is crossed by the fault extended to Mesozoic layers.

These examples necessitate the application of new methods of prospecting and research of oil and gas bearing in the regions with renewed hydrocarbon reserves.

All mentioned facts prove vertical fluid migration through faults being a principal condition of the hydrocarbon reserves renewal in developed deposits. Therefore the main indicator of fluid renewal is fault tectonics caused by tectonic activity at the present-day stage of geological history.

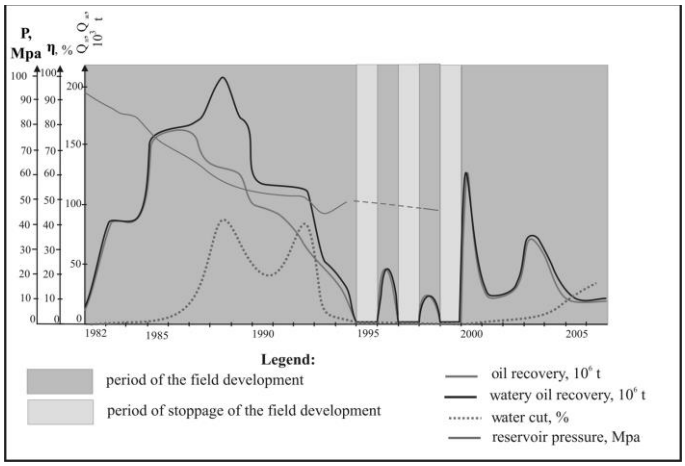

Fig. 3 Dynamics of development of the Hankala oilfield

Significant investigations of influence of the modern tectonic movement on formation and reformation of hydrocarbon deposits have been conducted by Kas'ynova N.A. The main objects of her research are oilfields of the Caspian Sea and the Ciscaucasia and Volgograd region. Kas'ynova N.A. have concluded that the number of initial reserves depends on intensity of Earth's crust moving. This dependence is most brightly shown on the example of gas fields that can be explained by high mobility of gas then oil. In addition, Kas'ynova considers oil and gas saturation to be dependent on existence of conductive channels in the form of vertical and horizontal fractures. The nature of horizontal fracture can be explained by tectonic-gravitational processes related to intensive immersion of Volgograd Leftbank during a modern stage of geological history.

Faults of platforms are known to be characterized by small amplitudes. In spite of modern technologies of exploration seismology, the problem of identification of platform faults still persists. Therefore identification of fault zones must include a whole complex of investigations – exploration seismology, distant methods, well survey, formation testing and a new method – thermobarogeochemical analysis of gas-fluid inclusions.

Kas'ynova's conclusion is confirmed by the results of the investigations carried out by scientists of the Departure of oil and gas Geology of South Federal University [5]. The object of their research is gas-liquid inclusions in the core samples selected from wells drilled within the zone of oil and gas accumulation with renewable reserves – the Kudinovsko-Romanovskaya Uplift (Volgograd region).

These investigations are based on analyses of distribution of paleotemperature, paleopressure, ion-saline and gas compounds of paleofluids enclosed in rocks in the form of gas-fluid inclusion. Gas-fluid inclusion is a defect area of the crystal lattice of minerals preserving "microconditions", and the trace amount of the past environment formed this mineral. They are closed physicochemical systems with specified characteristics – temperature, pressure, compound, concentration and aggregate state. Hereby gas-fluid inclusion is considered to be evidence of past geological processes (Fig. 4).

At the first stage of thermobarogeochemical investigation microscopical analysis of forty seven samples of core were carried out. At the next stage of investigation we selected seven core samples involving hydrothermal joint filled by calcite. Then we analyzed these samples by the use of vacuum deceptograph VD-6 recording intensity of gas release and level of vacuum. These parameters can be converted to amount of temperature and interpreted as maximal heating of sediments - paleotemperature.

On the obtained diagrams there are two peaks of activity. Amounts of the first peak range from 60°C to 100°C that can be explained as maximal heating of whole rock bed. It's interesting that minimal amounts of the first peak are registered in the central part of the zone, that by-turn is characterized as area of the least catagenetic transformation. Amounts of the second peak rise to 280°C that can be interpreted by local heating caused by higher geodynamic activity. The maximal intensity of gas release is registered in peripheral areas of the Kudinovsko-Romanovskaya Uplift characterized as a fault zone.

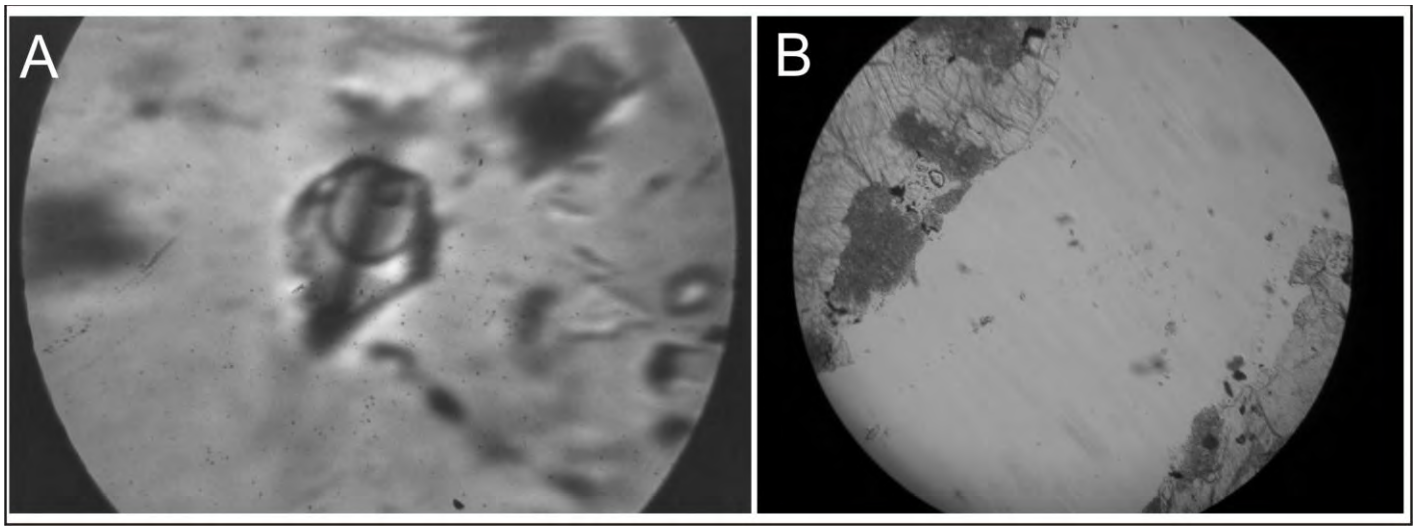

Fig. 4. Gas-fluid inclusion in the hydrothermal joint filled by calcite (A – core sample selected from the well of the Tersko-Caspian Foredeep; B – core sample selected from the well of the Kudinovsko-Romanovskaya Uplift)

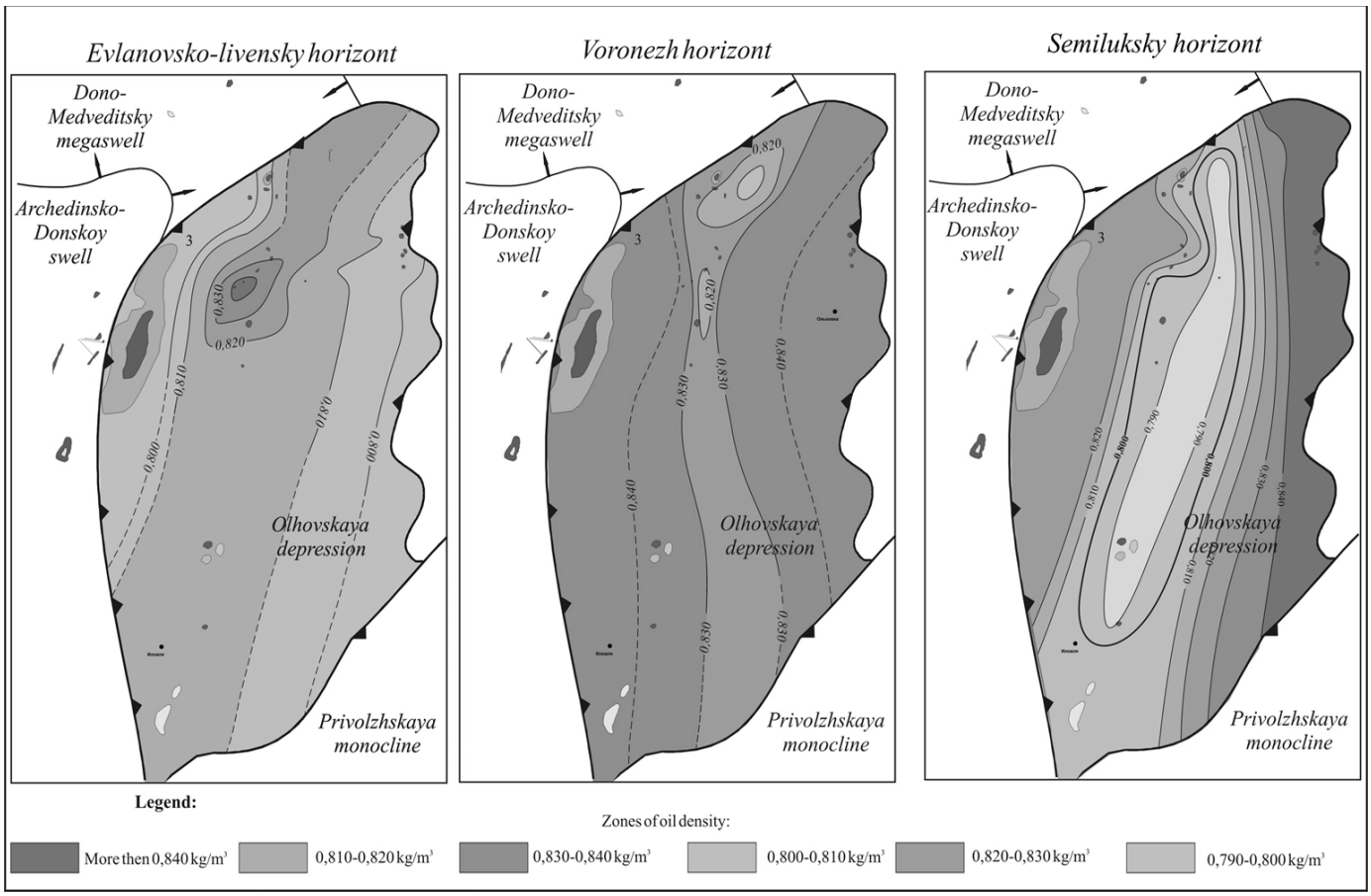

Fig. 5. Maps of oil density within the Kudinovsko-Romanovskaya Uplift

Thereby the results of thermobarogeochemical investigations make it possible to define zones of fault tectonic and are evidence of conducting quality of these faults.

Other informative approach in the study of the hydrocarbon reserves renewal is analysis of geochemical characteristics. Physicochemical properties are known to be effected by many factors such as catagenesis, hypergenesis, migration and long-continued development of oil deposits. Consequently important task of exploring is not only definition of general tendency of geological history but also prospect of modern geological and anthropogenic processes occurring during oil recovery. Considerable results in investigation of geochemical characteristic of the hydrocarbon reserves renewal have been achieved by Bochkarev A.V., Ostrouhov S.B., Sianisyan E.S., Sikorskaya S.V.

Depending on the degree of reliability, all geochemical criteria can be divided into two groups – relative and absolute (Sikorskaya, Sianisyan, 2014). Relative criteria include physical parameters dependent on many geological and anthropogenic factors – changing in oil density, oil viscosity, initial boiling. Maps of oil density of Evlanovsko-livensky, Voronezh and Semiluksky horizonts within the Kudinovsko-Romanovskaya Uplift have been constructed by scientists of South Federal University (Fig. 5).

Analysis of the maps makes it possible to mark out two areas – a zone of catagenetic impact and a zone of migratory impact. The central part of the Kudinovsko-Romanovskaya Uplift is characterized by decreasing of oil density with increasing depth that can be explained by growth in temperature and pressure. West and East parts of the Kudinovsko-Romanovskaya Uplift are characterized by inverse distribution of oil density. This anomaly is explained to be connected with entrance of a new portion of gas hydrocarbons and their accumulation in upper deposits. The most part of fault concentration is noted to be fixed in West and East parts of this tectonic element.

Absolute criteria are notable for credibility, but their deficiency is a small amount of data for identifying regularity. It is known that under hydrocarbon migration in the stream form, the number of criteria of migration decreases because of little impact of sorption, phase-retrograde and diffusion effects. Under vertical migration of gas streams through faults in adjacent oil deposits, ratios of i-alkanes/naphthenes, alkanes/arenes, benzol/toluene, pristane/phytane increase. Distribution of the ratio of pristane/phytane within the Kudinovsko-Romanovskaya Uplift is more significant. The maps of the ratio of pristane/phytane are correlated with the maps of oil density and zones of catagenetic and migration impacts. Such geochemical distribution proves the conception of two-step formation of oil deposits.

Other geochemical factor of hydrocarbon reserves renewal is distribution of n-alkanes in oil (Ostrouhov, 2011). Three types of hydrocarbons were defined on the basis of chromatography. The first type includes hydrocarbons with irregular character of n-alkanes distribution. On chromatograms of this type, it is only possible to define dominance of molecules with an even or odd number of carbon atoms. This type is inherent in oil deposits. The second type of hydrocarbons is characterized by decreasing in n-alkanes with increasing of the amount of carbon atoms. Such regularity is defined by exponential dependence that can be explained by presence of intensive mass exchange between gas and liquid substances in subsurface (Ostrouhov, 2011). This type is inherent in condensate deposits. The third type of hydrocarbons is of particular interest for forecast of hydrocarbon renewal. Several sections of n-alkanes distribution are marked out on chromatograms of this type of hydrocarbons. The first section includes n-alkanes C_6-C_{11}, conforms to condensate component and is similar to the second type of hydrocarbons (condensate deposits). The second section of chromatograms is defined by cubic equation and conforms to oil part of fluid. Ostrouhov proposes the definition of connection between hydrocarbon deposits and zones of active migration of new portions of hydrocarbons.

III. Conclusion

The mentioned investigations confirm the conception of two-step formation of hydrocarbon deposits in view of the theory of organic petroleum origin. This new approach has influenced planning of exploration work – in the 90-ies the Volgograd left-bank region was known as unproductive, but now it is the main exploration target. All wells drilled there are still producing. Such success can be explained by entering of new portions of hydrocarbons over the last twenty years, when intensive oil recovery has been passing from other deep layers.

Drawing an analogy with the geology structure and the history of other regions makes it possible to optimize exploration work in other regions [6].

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