

Chapter II.12

GYPSUM KARST IN THE SOUTH OF THE SIBERIAN PLATFORM, RUSSIA

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Carbonate, sulphate and salt deposits in the sedimentary rocks of the Siberian platform support extensive karst development that encompasses about 25% of the study region. Karst is associated with carbonate, gypsiferous and salt formations of Cambrian, Ordovician, Silurian and Devonian age. Sulphate karst is developed particularly extensively in the south of Priangarie (the Angara region), where the valley of the Angara river stretches across a 70 to 100km-wide zone of gypsiferous formations. The area comprises a high plateau, with main streams entrenched by as much as 200m.

The geology of the southern part of the Priangarie region is characterized by the occurrence of Lower and Upper Cambrian sedimentary rocks, as well as overlying lacustrine/continental deposits of Jurassic age. Among the Lower Cambrian deposits, only rocks belonging to its upper units (the Angara and Litvintsev members) crop out within the area. The Angara Member is composed mainly of different kinds of dolomite and dolomitized limestone, which are silicified at some levels, or contain numerous siliceous mottlings. More rarely the dolomitic rocks include intercalations of marl, limestone and quartzose sandstone. The rocks of the Angara Member are overlain conformably by the Litvintsev Member, which belongs to the upper part of the Lower Cambrian and the lower part of the Middle Cambrian. The Litvintsev Member is composed of grey, fine-grained, laminated dolomites and, to a lesser extent, massive and thickly bedded dolomites with numerous stylonitic partings. In the upper part of the unit thick beds (30 to 40m) of anhydrite and gypsum, as well as of gypsiferous dolomites, are common. The lower slopes of the Angara and Zalarinka river valleys, and slopes of numerous ravines, are cut within these rocks, and the beds are intensely karstified.

In the Shalotsky area the typical succession includes gypsiferous rocks and has the following pattern. A 10 to 12m-thick bed of dense, highly fissured and cavernous dolomite, overlies a gypsum-anhydrite sequence with dolomite intercalations. At a depth of 30 to 35m within this gypsiferous sequence is a 6m-thick layer of gypsiferous dolomites, with some minor gypsum intercalations. The massive fine-grained dolomites are underlain by the gypsum-anhydrite rocks. Dissolution features are abundant along the contact of the sulphate rocks with the dolomites, generally being represented by karst cavities that have been filled with clayey material or dolomite powder. Open cavities along the upper contact of the karstified rocks are rare.

Vologodsky (1965, 1975) distinguished three stages of karst development in this region, and these occurred during the Mid Cambrian, in pre-Jurassic times and during the Quaternary.

Evidence of Mid Cambrian karstification is found only in the Oka river basin. Here there are relict sinkholes buried beneath rocks belonging to the Upper Cambrian sequence, there are ancient carbonate breccias and there is a local reduction in the thickness of the beds that compri-

se the upper part of the Angara Member.

There is more abundant evidence of pre-Jurassic karstification in the region. This karst episode produced substantially more destructive effects than those related to more recent karstification. The pre-Jurassic karst development occurred predominantly in the south of the region, where Upper Cambrian deposits were removed by erosion long before the Jurassic. This stage is distinguished by the presence of extensive fields of kaolin-filled sinkholes and of regionally widespread breccias and brecciated dolomite beds, as well as by the effects of rock silicification in the upper parts of the Angara Member. Leaching of enormous quantities of sulphate and carbonate from the upper parts of the Angara Member caused thick horizons of dolomite to be converted to carbonate breccias. This resulted in substantial differences in the nature of the Angara Member as preserved in the northern and southern areas, both in terms of lithology and thickness. In the southern area gypsiferous rocks are poorly represented, having been largely dissolved during pre-Jurassic times, whereas they remain abundant and widespread in the north. Also in the southern area brecciated dolomites correspond stratigraphically to beds that were originally gypsiferous, with thicknesses 2 to 3 times less than those of the original sulphates. Substantial localized reductions in the thickness of the Angara Member (changes of to 50 to 100m thickness within 2 to 3km of outcrop) suggest that the karstification had a great and dominantly destructive effect.

A gypsum karst of Quaternary age is developed widely in the valleys of the rivers Angara, Oka and Belaja and their tributaries. At present practically the whole thickness the Angara Member has been subjected to karstification, with the effects being most intense in the upper part of the sequence.

The solute load of runoff from the gypsiferous rock areas is estimated at 170 t/km². Chemical denudation rates vary from 0.02 to 0.08mm/year. The overall surface lowering rate in geologically recent times is estimated roughly at 1m per 10 to 12 thousand years. Cumulative amounts of karst denudation of sulphate and sulphate/carbonate formations during the Quaternary are estimated to be approximately 70 to 80m and 20 to 30m respectively.

Morphologically, gypsum karst is typified by sinkholes, caverns, blind valleys, karst trenches and dissolution troughs (Pulina & Trzcinski, 1996). The superficial forms are represented mainly by sinkholes of corrosional and suffosional origin. Most old sinkholes are in the range 20 to 80m in diameter (rarely 100 to 120m) and 8 to 20m in depth. Groups of sinkholes that have fused together commonly form 150 to 200m-long depressions. Recent collapses are pit-like or pitcher-like in shape (immediately after their formation and before secondary modification). The maximum recorded sinkhole depth is 38m, although depths decrease rapidly with time due to in-washing of fill materials. Large sinkholes are confined to zones that are related to tectonic faults, particularly to areas where these cross each other. In some areas of well-developed gypsum karst in the Priangarie region the density of sinkholes reaches 200 to 250 units per km².

Caves are commonly located in distinct zones along the valley slopes. The largest caves are Balaganskaja and Khudugunskaja. These large caves, as well as the smaller ones (commonly 20 to 50m in length), were formed within zones of horizontal groundwater circulation, and a multi-level structure is common, reflecting changes of base level.

Intense economic development in East Siberia during recent years has had substantial impact

on the karst. In particular, activation (or re-activation) of karst processes has been induced by the creation of artificial reservoirs. For example, the growth of the Bratsky reservoir has led to dramatic changes to natural conditions along its shore areas (Problems of Protection..., 1993; Trzhtsinsky & Filippov, 1981). These changes have imposed accelerated rates of karst deformation, including the development of collapse sinkholes and subsidence trenches. Many of these have caused damage to buildings and constructions. Some shore zone areas have become unsuitable for industrial and even for agricultural use.

The intensification of gypsum karstification that followed construction of the Bratsky reservoir resulted in the development of new sinkholes and pits up to 40m deep, with volumes up to 7,000m³. Formation of sizable sinkholes, a typical effect during the early period of the reservoir's existence, was due to rejuvenation of palaeokarstic features. Sinkhole development in later years has been caused mainly by water table fluctuations induced by water level changes in the reservoir. Since the time of the initial impounding, the gypsum karst activity has not diminished, but has tended to expand its area of influence. The zone of sulphate karst activation induced by construction of the reservoir is now 6km wide. The maximum rate of appearance of new collapses occurs within a 0.5 to 1.0km-wide zone along the shore, where it ranges between 0.8 to 10.0 units per km² per year.

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