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Global Trends on Geological Origin of Limestone Deposits and Its Relation to the Hard Water Formation

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Abstract: In this paper, briefly we reviewed the global trends on geological origin of limestone and hard water formation. Hard water contains a significant quantity of dissolved minerals, such as calcium and magnesium. Many aquifers consist of the minerals beyond the limits suggested by United States of Geological Survey (USGS) and Water Quality Association (WQA). Global wide, limestone and dolomite deposits are occurred naturally and leads to the hardness of water. The hardness water causes many environmental and public health safety issues.

Index Terms: limestone, geological origin, ground water quality, global trends

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I. Introduction

Hard water contains a significant quantity of dissolved minerals, such as calcium and magnesium. Hardness of water is two types such as i. carbonate hard ness and ii. non carbonate hardness. The carbonate hardness is often called as "temporary hardness" because heating the water will remove it. It is caused by calcium and/or magnesium hydrogen carbonate. These are formed as carbonated rain water passes over rocks containing carbonate ions.

$H_2O(l) + CO_2(g) + CaCO_3(s) \rightarrow Ca(HCO_3)_2(aq)$.....1

$H_2O(l) + CO_2(g) + MgCO_3(s) \rightarrow Mg(HCO_3)_2(aq)$.....2

Non carbonate hardness is called "permanent hardness" because it is not removed when the water is heated. It is caused by calcium and/or magnesium sulphate. These are formed as water passes over rocks containing sulphate ions.

aq. + $CaSO_4$(s)Ca^{2+}(aq) + SO_4^{2-}(aq).....3

aq. + $MgSO_4$(s)Mg^{2+}(aq) + SO_4^{2-}(aq).....4

We showed the brief mechanism of hardness of water formation with the mineral salts and metals in **Fig.1.**

Fig.1 Hardness of water formation mechanism with the minerals and metals

Fig.2 shows the life cycle analysis of water[1]. The water cycle also known as the hydrological cycle of water. There are mainly 3 steps are involved I, precipitation, ii. evaporation, and iii. condensation. Water usually falls as rain onto a land mass and then percolates through the layers of soil and rock, it gains hardness. This hardness is due to the rain passed over the rocks and Ca, Mg minerals dissolved in the water.

Some researchers recently discovered that only 30 to 50% of the rain falls comes directly from the ocean. The rest comes from rain that fell earlier in the season and has been recycled through trees and soil and streams back into the atmosphere[1].

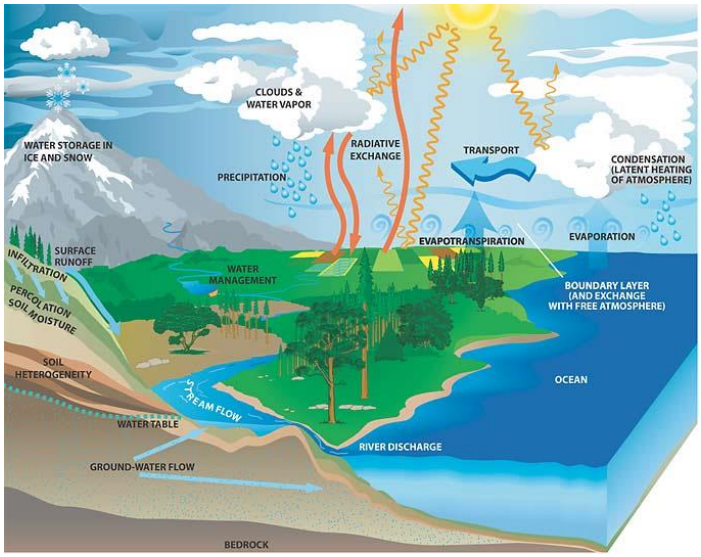


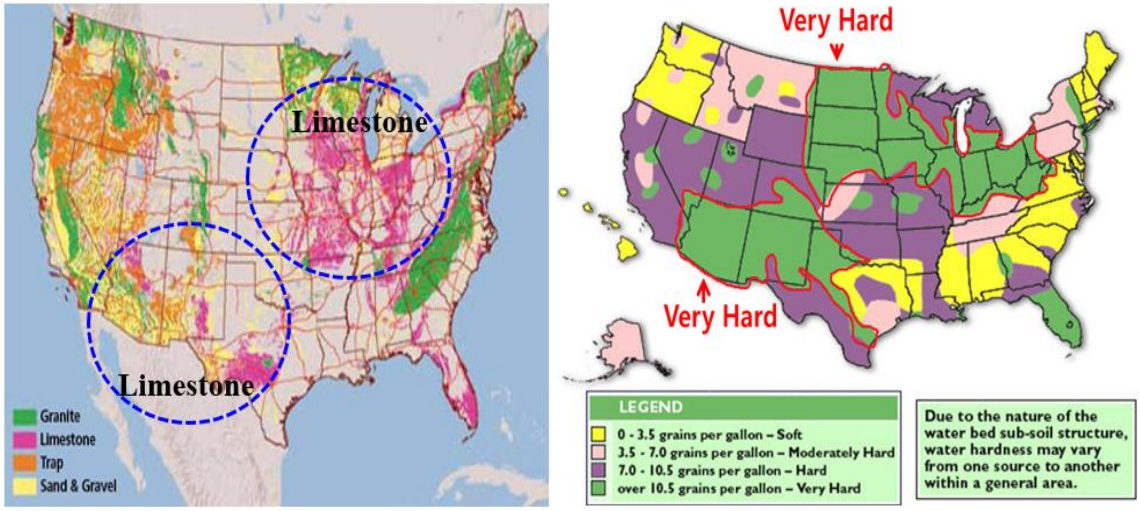
Fig.2 Life cycle of water

Hardness of water is measured in grains per gallon (gpg) also ppm units. United states geological survey and water quality association classified the hardness of water (Table-1).

Grains per gallon(gpg)	Milligrams per liter(mg/L) Parts per million(ppm)	U.S.G.S Classification	Water Quality Association
<1.0	<17.1	Soft	Soft
1 to 3.5	17.1 to 60	Soft	Slightly Hard
3.5 to 7.0	60-120	Moderately Hard	Moderately Hard
7.0 to 10.5	120-180	Hard	Hard
10.5	180 and over	Very Hard	Very Hard

2. Global trends of geological origin of limestone and related to the hardness of water
Case I: USA

According to USGS reports, natural aggregate is widespread throughout the conterminous United States, but the location of aggregate is determined by geologists. In some regions, rock, sand, and gravel deposits are geologically available in United States of America. In some areas particularly limestone is the predominant aggregate[2]. Here, we presented the limestone deposits and hardness of water images in Fig.2.



(a) (b)

Fig.2. (a) limestone deposits in USA **(b) hardness of water in USA.**

From this figure, we assumed the relation between limestone deposits and hardness of water is confirmed. When water passes through or over mineral deposits such as limestone/dolomite, the levels of Ca^{2+}, Mg^{2+}, and HCO_3 ions present in the water greatly increase and cause hardness.

Geologically and hydrologically carbonate rocks are existed in Berkshire County in Western Massachusetts and Columbia County, N.Y. The hard water formation is related to not only limestone deposits and also dolomite deposits[3,4] and it is presented in the Fig.3(a) and(b).

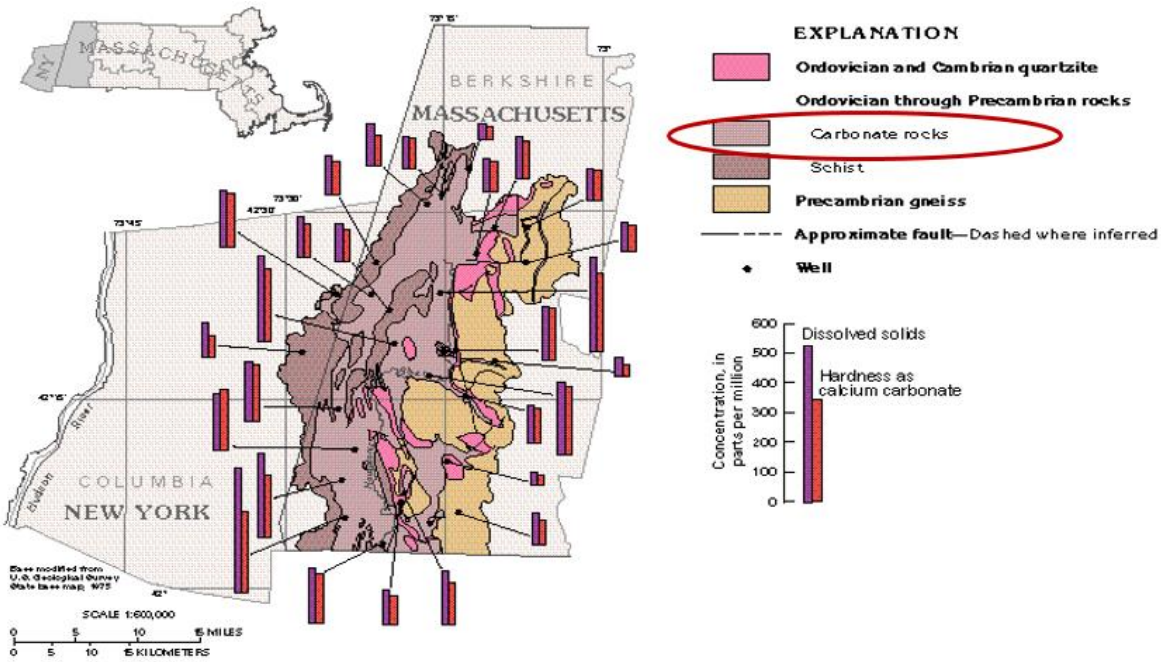


Fig.3(a) Carbonate rocks in the upper Housatonic river basin of Western Massachusetts

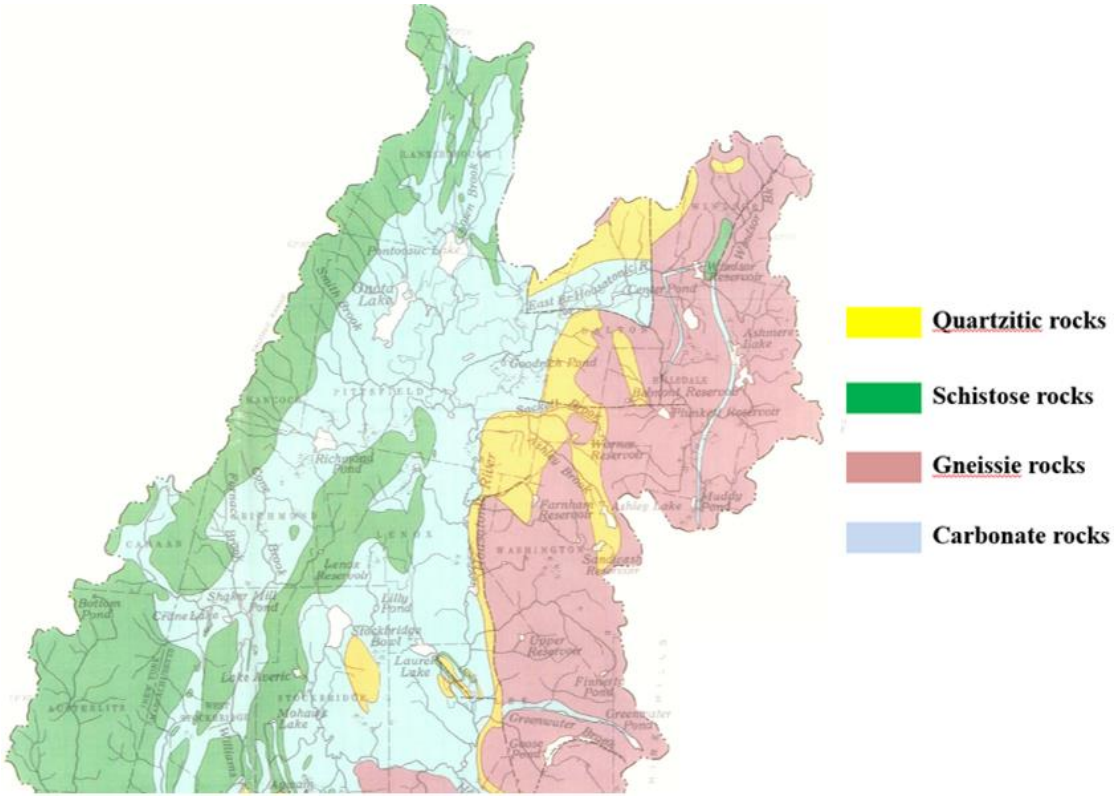


Fig.3(b). Generalised bedrock geology

The ground water quality was dependent on its geological and hydologic environment. The limestone deposit areas patcularly, the quality of water was changed. The relation between the ground water quality and geological origin of limestone formations are quite significant. The bed rock system consists of quartzite, sandstone, dolomite, marble, schist, and gneiss. Accodring to the USGS surveys and investigations concluded that greater hardness is due to limestone / dolomite deposit areas.

Case II: Canada

Hardness of ground water in carbonate-rock aquifers of the Lake Erie-Niagara Basin, Tonawanda Creek Area was observed[5] in the Fig. 4.

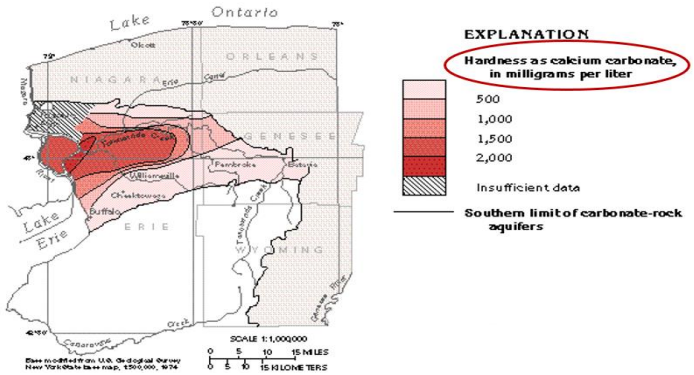


Fig.4. Calcium carbonate (limestone) rock deposits

Bedrock system of the Lake Erie-Niagara River Basin consists dolomite, and limestone. The distribution of these units at the bedrock surface, lithology and vertical sequence are described[6] in Fig.5.

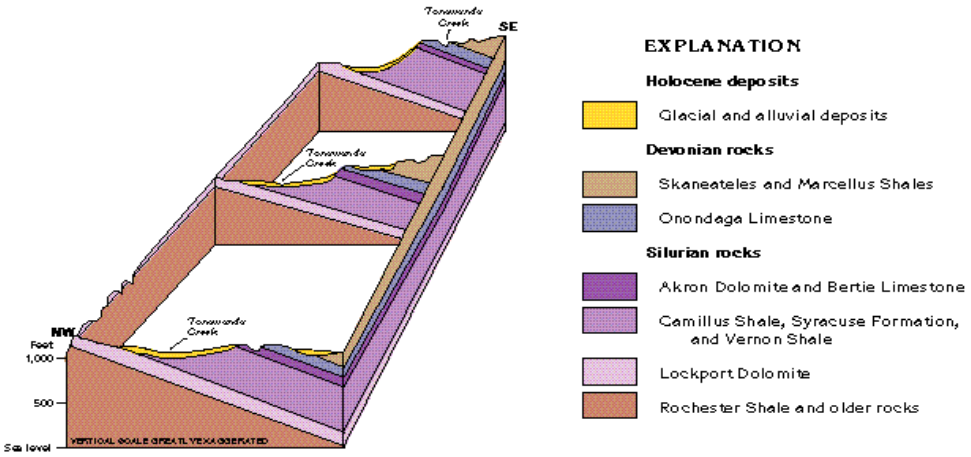


Fig.5. Calcium carbonate (limestone) rock deposits

The bedrock surface was deeply eroded by weathering and stream action prior to glaciation and by glacial scour during glaciation. Lake Erie-Niagara River Basin bed rocks consists of black to gray carbonaceous shale with minor calcareous beds and limestone layers and also the three aquifers near to the Lake Erie-Niagara River Basin, that consist of gypsiferous shale, dolomite and limestone at Silurian age.

Ground water moved from topographically high areas mostly toward the Niagara River

downstream. Calcite and dolomite are present throughout the basin especially in the Lockport aquifer and in the limestone aquifer. Water-yielding rocks in the basin contain four soluble minerals: calcite, which is the major constituent of limestone; dolomite; gypsum; and halite, or rock salt[3] (Fig.6).

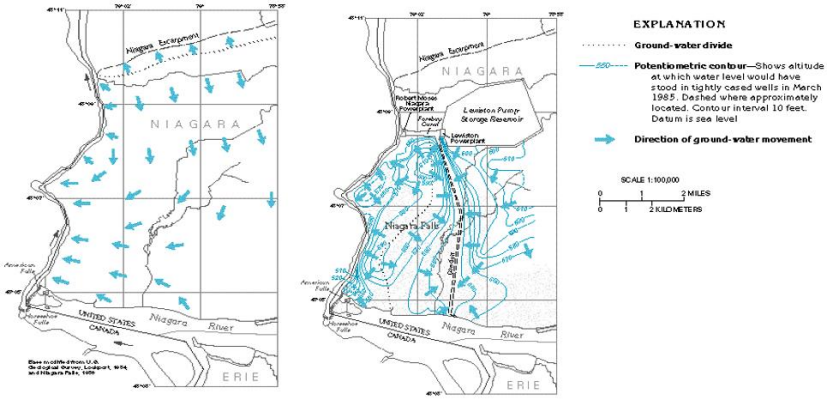


Fig.6. Water movement towards rock basins near Niagara River Basin

Case III: United Kingdom

Great Britain is largely made up of limestone and chalk, around 60% of homes in England and Wales are supplied with Hard Water[7]. Figure 7 shows the rate of hardness in mg/l as calcium carbonate in England and Wales. Hard water is wide spread across the entire UK, through some places have a richer composition than others[8]. The hardness is caused by the presence of minerals dissolved from the ground and rocks by the water.

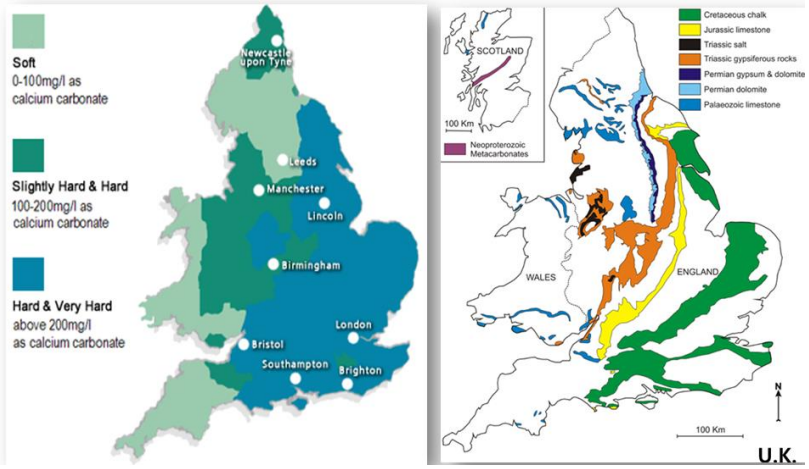


Figure 7. Hardness of water in UK and limestone deposits.

Case IV: India

Recently some researchers published an article about the ground water quality in limestone mining areas in India. They reported the impact of limestone rock mining and its impact on the water quality. Meghalaya has rich deposits of mineral resources such as coal, limestone, Sillimanite and

Uranium and 9% deposits of the total limestone resources of the country.

Among the investigated water samples, their hardness value has exceeded the prescribed limits (more than 300 mg/L). Due to environmental implications of limestone mining, water becomes more harder[9].

3.Conclusions

The USGS investigations data confirms the hardness of water and ground water quality is absolutely from presence of limestone and dolomite minerals in the water. A major global concern at present is that the world will run out with low quality of water. The most emerging global water problem of the future will be water quality. According to The World Water Organization (a U.S.based non-profit Association), around 1 billion global population in 2012 did not have access to safe drinking water. As per USGS the water hard ness levels are below 17.1ppm or <1.0 gpg is used for drinking water. In this paper, we reported the global trends of geological formation of limestones causes to natural hardness of water. For the safe drinking water we need to develop technologies for the scale prevention.

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