19 Hydrogeology of Hard Rock Aquifer in Kashmir Valley: Complexities and Uncertainties

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INTRODUCTION

Groundwater occurs in varied geological formations. Its occurrence in geological system is controlled mainly by the lithology (porosity and permeability) and structure (fractures, faults, dykes). The unconsolidated sediments referred to as continuous media, although vulnerable to contamination under shallow conditions, always form important source of water due to appreciable porosity and permeability. However, the water supply from these aquifers is dwindling worldwide due to overexploitation, global warming, easy exploitation, poor management etc. As the demand of freshwater exceeds rapidly than its renewal, the groundwater levels have gone down rendering a good number of wells dry. Hard rocks can also be good aquifers only if the secondary porosity is developed in the form of fractures or solution cavities and/or weathering. Fortunately all consolidated subsurface rocks are fractured to some degree with a scale ranging from microcracks to crustal rifts (Bonnet et al., 2001). The fractures generally increase the hydraulic conductivity of the rocks if the discontinuities are more permeable than the parent rock. Sometimes fractures may form barriers to flow if the contained material is less permeable than the host rock. Geological formations with fractures, solution cavities and large openings are referred to as discontinuous media. The occurrence, exploration and exploitation of groundwater in these media continue to intrigue and challenge hydrogeologists (Narasimhan, 2005) due to very high heterogeneity and anisotropy. Karst is commonly considered as the result of the solution process of carbonate rocks, viz., limestone and dolomite (Bakalowicz, 2005). Generally, fractured media do not constitute highly productive aquifers due to limited fracture dimensions. However, most carbonate rocks are karstified during geological time, with the development of poljes, sinkholes, dolines, caves etc. thereby forming highly productive aquifers. Generally less than 50 ky are required for development of an integrated karst network (Atkinson et al., 1978; Dreybrodt, 1998).

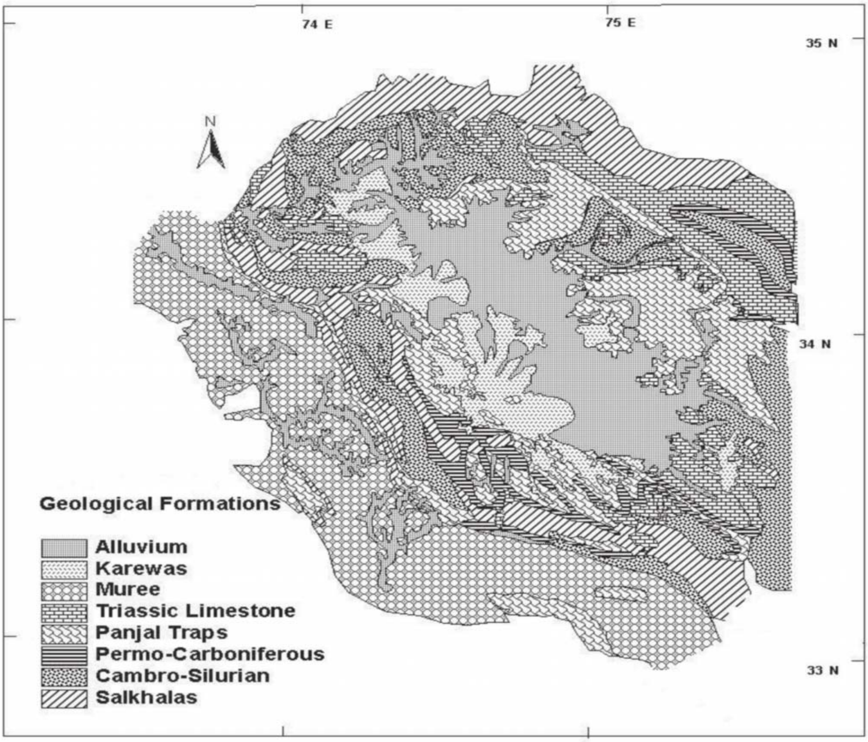

Figure 1. Geological map of Kashmir (modified after GSI, 1977)

Kashmir Valley (Jhelum basin), one of the many NW-SE oriented depressions of regional dimensions of Himalayan mountain system is an intermontane valley bounded by four major ranges; Pir Panjal Range towards SW, Saribal Range SE, Great Himalayan Range towards NE and Qazinag Range towards NW. The valley is about 135 km long and 40 km wide with a floor which in the Jhelum floodplain is only 1585 m above sea level, covering an area of about 12,757 km^2. It lies between the longitudes 33°25′N and 34°32′N and latitudes 74°0′E and 75°30′E. The Valley has been described as a great synclinal (de Terra and Paterson, 1939; Wadia, 1975), seated on the back of a vast nappe, Kashmir nappe (Wadia 1931). Spate and Learmonth (1976) described the complexity of physiographic features of Kashmir Valley as "predominance of majestic mountain ranges with snow clad peaks, large longitudinal valleys of subsequent streams occupying deep gorges, transverse gorges cut across the ranges by antecedent streams, strategic mountain passes alluvial plains, preponderance of glaciers and patches of snow fields, plateau like features developed in thick accumulations of the Pleistocene glacial moraines (Karewas) and numerous glacial lakes". Geomorphologically the area is represented by a valley, high structural hills, small mounds of Karewa in the valley portion and colluvial fans below the hill slopes (Singh and Sharma, 1999). This complexity of physiographic units with numerous faults gives rise to complex aquifer system. However, in this article an attempt is made to describe the possibility of occurrence of groundwater in geological formations on a broader scale.

Diversified geological formations, lithological variations, tectonic complexity and geomorphological dissimilarities of Kashmir give rise to a variety of groundwater situations. The Valley is filled with soft rocks, unconsolidated sediments of Quaternary and Recent age, garlanded by and rested on hard rocks mostly volcanics and limestones (Fig. 1). Being part of the Himalayas, it has a complex tectonic history, consisting of diversified rocks that are folded, faulted and jointed. Groundwater occurs in both soft as well as hard rocks.

SOFT ROCK AQUIFERS

The Quaternary to Recent rocks comprising the alluvium and Karewa deposits are the important continuous media or unconsolidated formations. These sediments are comprised of clays, silts, sands, gravels etc. and may be good aquifers.

1. Karewas

The Karewas preserve a record of sediment deposition in a lake formed during the Late Neogene to Quaternary period (Bhatt, 1975, 1976; Singh, 1982; Burbank and Johnson, 1983) covering an area of about 5000 km^2. These unconsolidated fluvio-lacustrine deposits are exposed in the river valleys and the plateau margins of the Kashmir Valley, comprising alternations of clays, silts, sands with occasional boulder beds. The gravity surveys supported by refraction surveys, carried out in the Valley, indicate their maximum thickness as 2000 m resting on Triassic Limestone or Panjal Traps (Datta, 1983). Exploratory drilling carried out by ONGC in search of hydrocarbon; at Chattargam (very close to Yachigam, Pulwama) where the Karewa sediments encountered up to the depth of only 515 m below which 600 m of Triassic Limestone have been drilled and at Narbal where Karewa sediments directly overlie Panjal Traps at a depth of only 550 m. This indicates the narrowing of the Karewas towards the peripheral areas. Isolated exposures of Karewas form minor hillocks in the Valley. The frequent alternations of clay with sand and boulders, sub-horizontal disposition, almost gradational character and undulating nature of the Karewa deposits minimizes the possibility of occurrence of potential aquifers in these deposits. Groundwater in the Karewa aquifers are mostly Mg(Ca)-HCO_3 type and have characters of interaction with volcanics indicating their reservoir in Panjal Traps (Jeelani 2004, 2005).

2. Alluvium

The central part of the Valley, which mostly covers the flood plains of the river Jhelum and adjoining streams, is filled with Recent alluvium. These deposits include alluvial tracts, flood plains, river terraces and talus and scree fans. The deposits are mostly water logged. The groundwater at some places along Jhelum River has evolved to chloride type and the total dissolved solids have increased to ~1500 mg/L. Besides, the groundwater is mostly associated with methane gas. The wells sunk in these deposits were abandoned by the people. However, towards the periphery the quality of groundwater is excellent of Ca-HCO_3 type. The groundwater in these areas has signatures of interaction with carbonates reflecting Triassic Limestone as the reservoir.

The exploratory drilling operations carried out by ONGC, CGWB and Directorate of Geology and Mining, Jammu & Kashmir, suggest that the aquifers are highly erratic, mostly lenticular with lesser aerial and vertical extent.

HARD ROCK AQUIFERS

The soft rocks are surrounded and underlaid by hard rocks. Broadly hard rocks of Kashmir can be divided on the basis of their distribution and dimensions into two broad divisions; Panjal Traps and Triassic Limestones. These rocks have been subjected to tectonic disturbances through geological time with the evolution of Himalayas, resulting into the deformation in the form of fractures. The fractures in the Triassic Limestone have progressively developed to karst due to solution action.

1. Panjal Traps

The Panjal Traps are upper Middle Carboniferous to Permian basic volcanic rocks of Kashmir. These are fine grain, generally light coloured, massive and hard block lavas with columnar and conjugate joints (Middlemiss, 1910; Bhat et al., 1881). The Panjal Traps are extensively developed with estimated thickness of about 2500 m. Active tectonics have developed the secondary porosity in the Formation, making it a productive aquifer. A number of perennial springs with a discharge of not exceeding 20 L/s emanate through it. The perennial and less fluctuating discharge of the springs reflects the productivity of the aquifer. The famous Chashma-Shahi spring emanate through this aquifer. The water is sweet and digestive, and was used by people from time immemorial. Pandit Jawahar Lal Nehru used to get this water to Delhi. The groundwater of this formation is really a mineral water of Ca(Mg)-HCO_3 type. Presence of a number of trace elements, Fe, Cr, Cu, Mn, Zn, Co, Ni, F etc., although within the drinking water quality standards prescribed by World Health Organisation (WHO) and Indian Standards Organisation (ISO) has categorized the groundwater within this aquifer into the excellent quality.

2. Triassic Limestones

Of the three epochs of the Mesozoic era, only Triassic is well developed and lies conformably over Paleozoic. Triassic limestone consists of a thick series of compact blue limestone, argillaceous limestone and dolomitic limestone and covers a large area of Kashmir, with a thickness of about 850 m (Middlemiss, 1910; Wadia, 1975). The groundwater effluence takes place as natural springs through Triassic limestone with fairly high rate of discharge ranging from a few L/s to 1800 L/s (Jeelani, 2005). The perennial nature and high and fluctuating discharges of these springs are indicative of the extent of development of karstification and productivity of the formation. Historical famous springs beautified by Mughals include Verinag, Kokernag, Achabal, Andernag, Martandnag, etc. The groundwater of this formation is of Ca-HCO_3 type.

Groundwater Development

Although groundwater development in Kashmir Valley is at its first stage, the demand for groundwater is increasing due to unreliable and/or inadequate surface water or supplied water. The people started groundwater exploitation to meet their demands but abandoned the wells due to poor quality and/or association of clay and silt particles and/or drying within a small period in alluvium and/or Karewas as the wells were drilled on non-scientific basis. Due to scanty precipitation, mostly in winter, the Valley has witnessed drought from 1999 to 2004. Some springs and wells totally dried up. There was a drastic reduction (about one-third) of discharges of all perennial springs. Most of the areas were without water for drinking and other domestic purposes. The agriculture was the main to suffer. Because of increased water demand, the abstraction of the scarce groundwater resources from shallow aquifers, that are generally lenticular with less aerial and vertical extent, has led to the drying up of wells in many parts of the area, and the farmers could not sustain their agricultural activities.

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