Groundwater for Sustainable Development 5 (2017) 131–136

Contents lists available at ScienceDirect

Groundwater for Sustainable Development

journal homepage: www.elsevier.com/locate/gsd

Radial anisotropy technique to target fractured aquifer in Precambrian Metamorphics: An exemplar from Eastern India

Rajesh Prasad[a,b], Tapas Acharya[a,*]

[a] Department of Geology, Hooghly Mohsin College (University of Burdwan), Chinsurah 712101, India
[b] Geological Survey of India, State Unit, Gujarat, Gandhinagar, India

ARTICLE INFO

Keywords:
Radial anisotropy
Lineament
Fracture
Groundwater
Foliation

ABSTRACT

Prospecting of groundwater in sub-surface horizons is a major challenge in Precambrian metamorphic terrains, e.g. the Purulia district of West Bengal, providing little scope for locating groundwater. However, detailed study of the Fracture-Correlated Lineaments (FCL) in variably fractured metamorphic terrains can give vital hydrological clue in selecting sites for tube wells with promising discharge of groundwater. This is an attempt to identify the hydraulically significant FCL using twin approach of surface geological investigation and radial anisotropic method. An integrated approach was adopted based on study of bedrock fractures, weathered-zone profiles, hydrological data with use of radial anisotropy method by Georient and Surfer softwares; revealing directional dominance of hydraulically significant FCL along 100–140°, concordant to regional foliation-trend of granite gneiss, and also along 15–40°, perpendicular to regional foliation-trend of phyllite, mica schist and epidiorite. The litho-stratigraphic preference of hydraulically significant FCL was found maximum for phyllite (38%) followed by mica schist (26%), epidiorite (21%) and granite gneiss (15%). The FCL pattern shows concurrence with thick weathered mantle, and high groundwater productive zones. The findings validate the usefulness of radial anisotropy as an important technique for identification of hydraulically significant FCL, and encourage their applicability in groundwater development in case of Precambrian metamorphic terrains.

1. Introduction

Fracture-Correlated Lineaments (FCL), often variably referred as fracture traces, are naturally formed linear surface features that bear correlation to subsurface fractures but can be interpreted directly from satellite imagery (Acharya and Basumallik, 2012; De'gnan and Clark, 2002; Lattman and Matzke, 1961; Lipfert et al., 2001; Matzke, 1961). These structures are of immense importance in hydrologic and oil investigations (Brown, 1994; Dhakate et al., 2008; Lattman and Parizek, 1964; Mah et al., 1995) and structural geologic problems (Acharya et al., 2007; Rahiman and Pettinga, 2008; Kazemi et al., 2009). Field study of FCL by different workers (Gleeson and Novakowaski, 2006; 2009; Magowe and Carr, 1999; Owen et al., 2002; Sander et al., 1997) seems promising in locating of dug wells, tube wells and drill wells in crystalline metamorphic and igneous terrains. Detailed investigations for characterization of FCL and hydraulically significant fractures are of paramount importance in case of Precambrian metamorphic rocks, particularly those that dominate in the water starved fluoride affected regions of westernmost part of West Bengal, India.

The main objective of this study is to target zones of hydraulically significant area in Precambrian metamorphic terrains. This can be achieved by the study of FCL by a new approach of new approach of 'radial anisotropy' that involves software application on surface geological data.

The study is carried out in and around Balarampur in Purulia district of West Bengal, extending between 23°00'52" and 23°07'41" North latitudes and 86°10'00" and 86°22'30" East longitudes (Fig. 1). The area (252 sq. km) is underlain by jointed/fractured metamorphic rocks marked with lineament swarms (Fig. 1). The variable bedrocks are Chhotanagpur Gneissic Complex, consisting varieties of granite gneisses (i.e. quartz-biotite granite gneiss and porphyroblastic granite gneiss) and the Singhbhum Group of rocks, comprising chiefly of mica schist and phyllite (Fig. 1) of Proterozoic age (Baidya, 1992; Gupta and Basu, 2000; Biswas and Sharma, 2016). Steeply dipping NW-SE trending foliations are consistently developed throughout study area (Geological quadrangle map 73 I, 1948). The South Purulia Shear Zone (SPSZ) that trends almost E-W along northern margin of Singhbhum Group of rocks passes through south of Balarampur and exhibits features indicative of brittle-ductile deformational regime (Bhattacharya, 1989; Dasgupta, 2004; Biswas and Sharma, 2016). Few studies were carried so far on

* Corresponding author.
E-mail address: tacharya3@yahoo.com (T. Acharya).

http://dx.doi.org/10.1016/j.gsd.2017.06.002
Received 28 March 2017; Received in revised form 14 June 2017; Accepted 14 June 2017
Available online 15 June 2017
2352-801X/

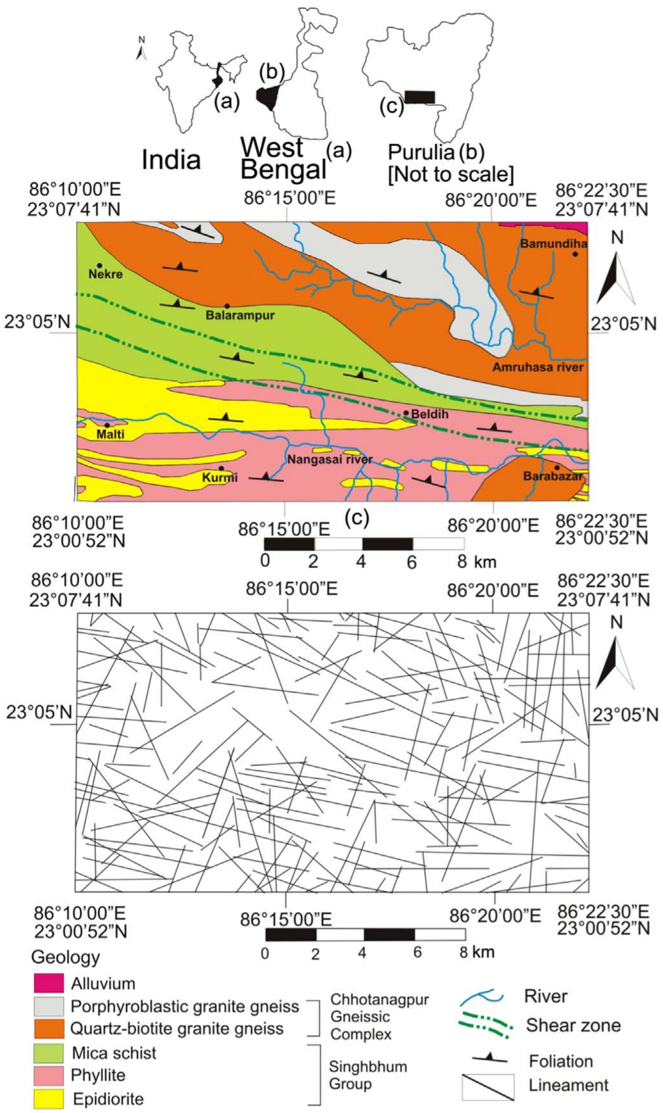

Fig. 1. Location map of the study area in and around Balarampur, Purulia district, West Bengal, India showing geological features and lineaments.

FCL and subsurface bedrock fractures in and around Balarampur region (Acharya et al., 2012; Acharya and Basumallik, 2012; Acharya and Chatterjee, 2010; Acharya et al., 2007; Mallik et al., 1983; Nag, 1999).

2. Method

In the study area, FCL were identified by Acharya and Basumallik (2012) adopting the method of Mabee et al. (1994, 2002). In this paper, a new method named radial anisotropy is applied for analysing the hydraulically significant FCL. The methodology of the radial anisotropy technique is described in a flow chart (Fig. 2). Hydrological data are used as inputs to above technique. Anisotropic direction distribution is detected to match well with anomalously high occurrence and length of FCL1. The methodology includes: (a) Lineament study (b) Fracture frequency analysis (c) Hydrological and weathered zone thickness analysis

2.1. Lineament study

Lineament map (Fig. 1) has been prepared from the Geocoded 73-I/4, 73-I/8 (1) and 73-I/8 (2) satellite imageries of IRS-P6 standard (band 2 3 4) false colour composite (FCC) on the base map, prepared using the Survey of India toposheets numbered 73-I/4 and 73-I/8 at 1:50,000 scale. Lineament map has been prepared by detecting and tracing lineaments from satellite imageries on the basis of textural, soil tonal, vegetation, topographic and drainage linearities (Lillesand 1989; Drury 1990; Gupta 1991) by visual interpretation. The non-structural and 'false' lineaments have been eliminated after comparing lineament map with the corresponding toposheets (73-I/4, 73-I/8) and field verification leaving the 'geologic lineaments'.

A total number of 72 FCL were analyzed in this study. Acharya et al. (2012) suggested that FCL, with fracture frequency > 10 /m of the correlated fractures, are hydraulically significant. These FCL were further grouped in two classes based on their hydraulic significance - (i) > 10 /m fracture frequency (FCL1) and (ii) < 10 /m fracture frequency (FCL2). The 72 FCL were thus grouped into 37 FCL1 and 35 FCL2. Directional analysis of the two FCL sets thus derived was represented in rose diagrams (Fig. 3) using Georient software and the pattern revealed similar directional abundance.

For further differentiation of FCL1 and FCL2, radial anisotropy method (Table 1)were used which took into account directional difference of the percentage of number and length of FCL datasets radially at 10° interval, and projecting them spatially to visualize the obtained result. Scatter plots of difference percentages of number (Table 2 and Fig. 4a) and length of FCL1 with FCL2 are plotted against the FCL trend separately (Table 3 and Fig. 4b) providing two prominent directions along 100–140° and 15–40°, along which the maximum radial anisotropy of FCL1 with respect to FCL2 exists in each parameter concerned (i.e. Number and length of FCL), indicating higher concentration of FCL1 (hydraulically significant FCL1). Along these directions (100–140° and 15–40°) obtained from the radial anisotropy, FCL1trending along 100–140° are found to be concordant with regional foliation trend and those trending along 15–40° are perpendicular to regional foliation trend. Upon projecting spatially FCL1 trending along 100–140° are found to lie dominantly on granite gneiss and FCL1 trending along 15–40° dominantly on phyllite, mica schist and epidiorite. The high radial anisotropy ranges (100–140° and 15–40°) include 21 FCL1,of which 38% are found in phyllite, 26% in mica schist, 21% in epidiorite and 15% in granite gneiss, indicating the litho-stratigraphic affinity of occurrence of hydraulically significant FCL1.

2.2. Fracture frequency analysis

Frequency of joints/fractures, measured as number of joint planes of a particular set crossed in a perpendicular traverse of 1 m. It is assumed that more closely spaced fractures with higher frequency may represent more potentially transmissive bedrocks (Mabee and Hardcastle, 1997; Lee et al., 2010). Outcrop measurements at each site are used to generate fracture frequency, which are then up-scaled and interpolated to the scale of the study area following the 'point kriging method' of geostatistical gridding, estimating the values at the points of the grid nodes (Golden Software Inc, 2010; Abramowitz and Stegun, 1972). This process yields a continuous fracture frequency contour map (Fig. 5) revealing the spatial variation of the frequency data throughout the study area using the software Surfer (Golden Software Inc, 2010). An overall low fracture frequency value along with some pockets of moderate values is evident in gneissic rocks. Frequency values are sporadic and highly anisotropic with pockets of low and moderately high values