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Graphical Signature Recognition of Fluid Geochemistry of Hot Springs in Peninsular and Extra-Peninsular India

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Abstract
*In continuation of a comprehensive guide to the characterization of the fluid geochemistry of Peninsular and extra-Peninsular hot springs, in the present study, the author illustrates multiple graph lines or weighted variables in a Google Excel sheet using the same data weighted by a weighting factor (the principal component loadings in this instance), which are nothing but the correlations between variables and factors. A **weighting factor** provides a weighted variable value for each observation in a data set.*

With the characteristic inverse phenomenon exhibited by multiple graph lines or factor weighted variables, the research affords a fascinating new insight into the origins of the two distinctive suites of fluid geochemistry of tectonically two diverse regions so close by yet so conspicuously distinctive.
Keywords*: Variables, Data Set, Weighting Factor, Weighted Variables, Principal Component, Loadings, Peninsula, Extra-Peninsula, Correlations*

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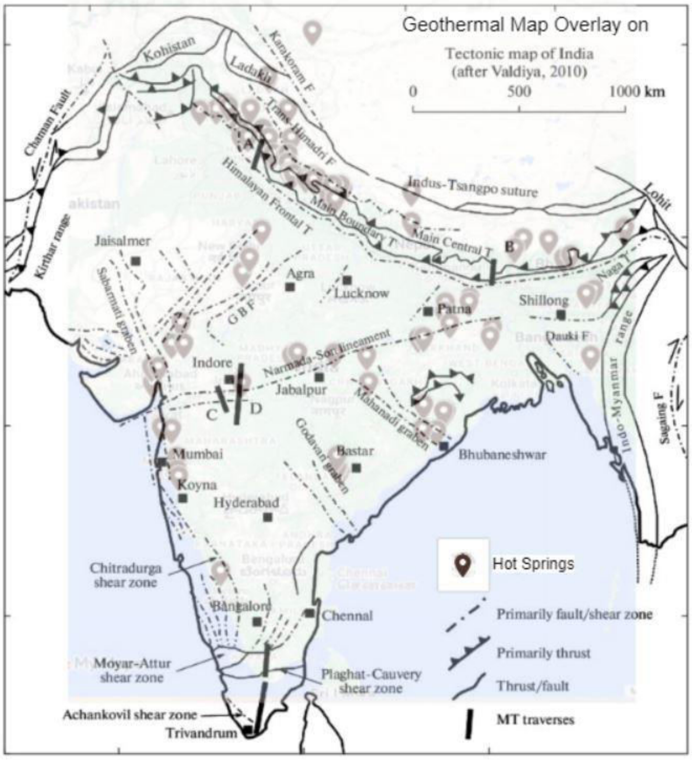
I. INTRODUCTION

Two sets of spatially dependent multivariate geothermal data representing two spatially distinctive regions of diverse geologic-tectonic settings – one from 2400 km long arcuate belt of tectonically active Extra-Peninsular Himalayan region and the other from Late- Precambrian or Proterozoic mobile belts in the Central Highland in otherwise a stable or shield landmass of Penininsular India, were subjected to robust statistical techniques



Exploratory Factor Analysis followed by multiple regression analyses to find out the genesis of geothermal hot springs spread over these areas conspicuously coinciding with the respective tectonic zones of different degrees of severity (Amitabha Roy,2023). The objective of Exploratory Factor analysis is to reduce a large number of variables into fewer number of factors or in other words to separate significant few from insignificant many variables.

The multiple linear regression analysis of multivariate data is aimed at explaining variability in dependent variable by means of one or more of independent or control variables. A multiple regression model is used when there is more than one independent variable affecting a dependent variable. While predicting the outcome variable, it is important to measure how each of the independent variables moves in their environment and how their changes will affect the output or target variable. Here in multiple regression analysis too choice of relevant variable (IV) out of many is an issue. One should never enter all the available variables at the same time. Carefully consider which independent variable is distinct or whether relevant to the problem. The first and the most reliable option adopted in the present study is to use factor analysis which creates a small number of factors that account for most of the original variables' information in them but which are mutually uncorrelated.

Both these Exploratory Factor and Multiple Regression analysises corroborate each other in deciphering the origin of these two suites of fluid geochemistry.The model study distinguishes non-magmatic thermal sources as K-Na-HCO3 for Peninsular springs as against the magmatic thermal sources as Cl-HCO3-SO4-Na type of Extra-Peninsular springs. The regression analysis revealed two statistically significant suites of fluid geochemistry – 1. The overall salt assemblage and concentration of Cl-HCO3-SO4-Na-F or chloride rich water suggest the existence of hydrothermal magmatic system operating in geotherms of Extra-Peninsular India and **2.** Peninsular springs of K-Na-HCO3 bicarbonate rich waters with low SO_4^- content and relatively higher contents of HCO_3 compared to other anions SO_4, Cl and F suggestive of a non-magmatic origin.

II. Methodology Adopted

In the present study, factor F1 of unrotated PCA was considered for both extra-Peninsula and Peninsula. The question may arise as to why PCA as well as F1 were preferred. The reason behind the choice is 1) that F1 of PCA bears a large number of variable assemblages and 2) that Factor 1 contains a common item TDS in both Peninsula and Extra-Peninsula. These preferential choices made interpretation more explicable in the light of earlier findings as regards the characterization of fluid geochemistry inherent in the two regions.

EXTRA-PENINSULA		PENINSULA	
Unrotated PCA	Rotated VARIMAX	Unrotated PCA	Rotated VARIMAX
F1 Cl-,SO4-,Ca-, Na-, K-,B-TDS-	F1 SO4, Ca, TDS	**F1** HCO3, Cl, SO4, Na, K, TDS	**F1** pH- , HCO3, SO4. K, TDS
F2 HCO3, SiO2	**F2** HCO3, F, SiO2	**F2** SPCMHO*,Ca, Mg, Na	**F2** SPCMHO*,Ca,Mg, Na
F3 Mg-as regard	**F3** HCO3-, Mg-, K-	**F3** SiO2	**F3** Cl
F4 Cl -	**F4** Cl-, F-	**F4** B, F-	**F4** F-, SiO2-

SPCMHO/Cm* - is correctly defined as the electrical conductance of 1 cubic centimeter of a solution at 25 °C used to estimate the salinity , ionic strength and concentrations of major TDS solutes in natural waters.

The same original raw data (Amitabha Roy, 2023) is weighted by a weighting factor (the principal component loadings in this instance), which are nothing but the correlations between variables and factors. A **weighting factor** provides a weighted variable value for each observation in a data set using FSCOR = X * B, where X are the analysed variables and B is the corresponding factor or component loading (or weight) on the variables. In the present study, Y (lat) and X (long) are redundant and left for future research with the aid of trend surface analysis.

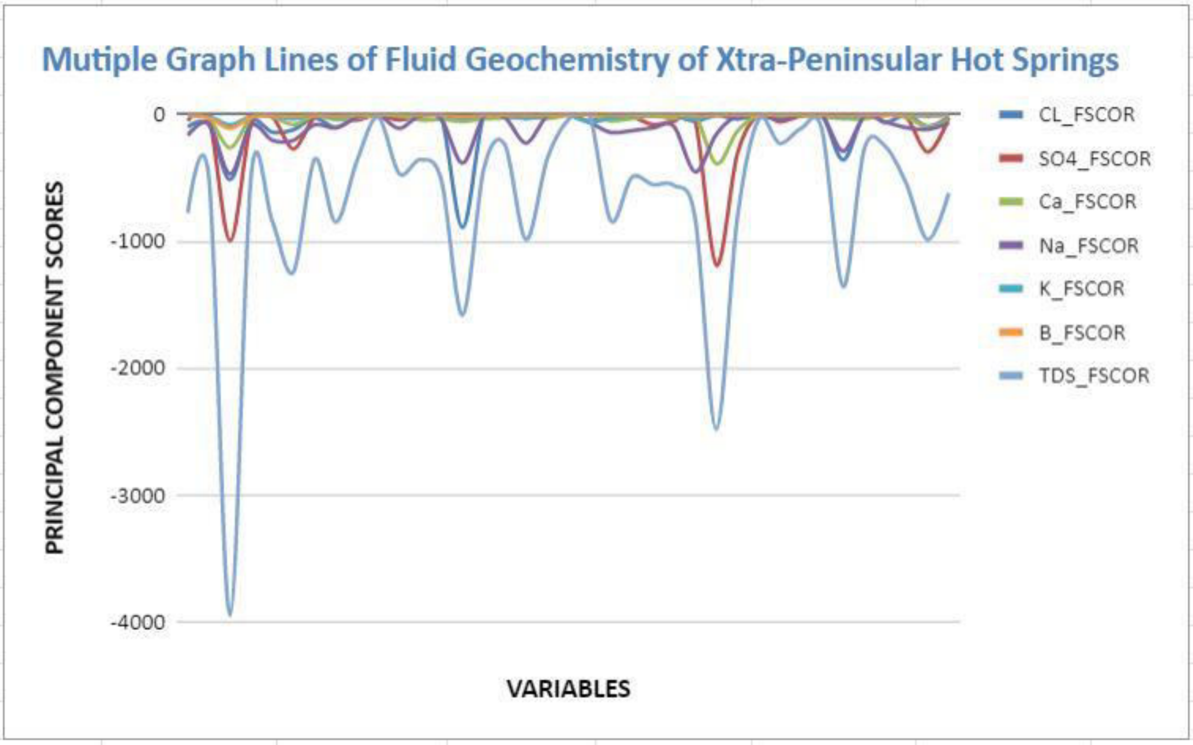
Data Set -1. Weighted Data by a weighting factor (Component loading): Extra-Peninsula

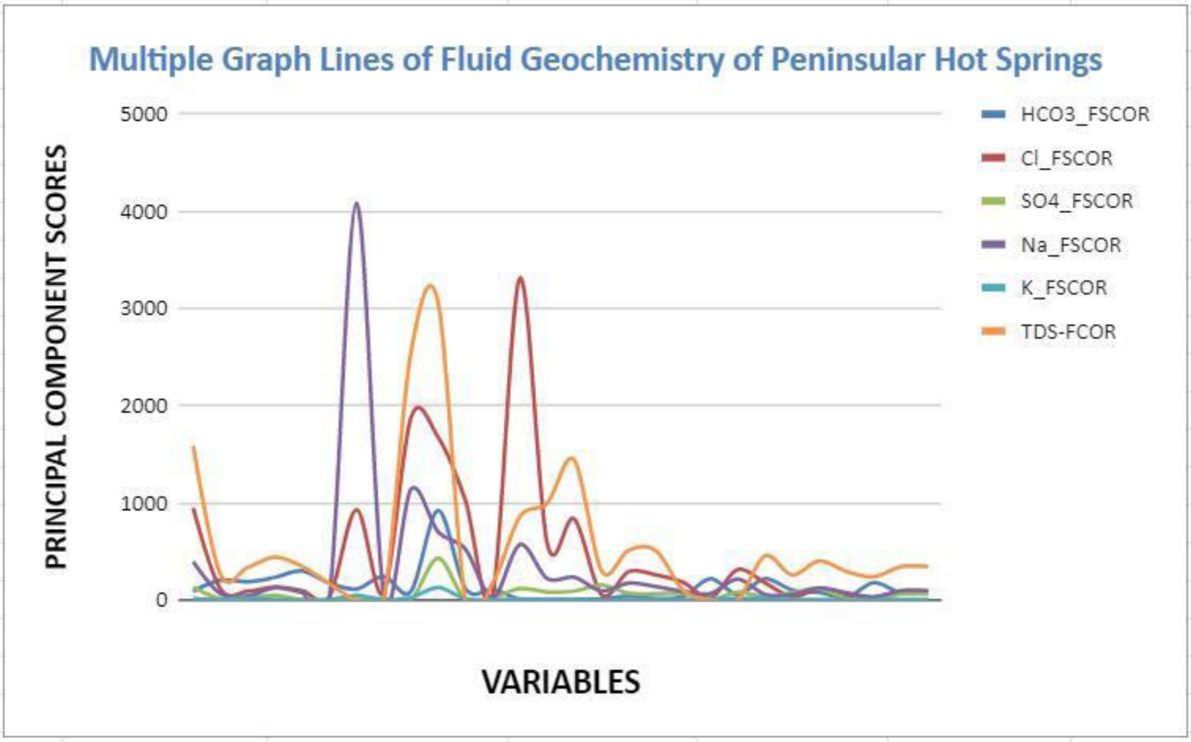
Y	X	CL_FSCOR	SO4_FSCOR	Ca_FSCOR	Na_FSCOR	K_FSCOR	B_FSCOR	TDS_FSCOR
28.15	77.04	-97.8	-49.6	-10.78	-163.8	-9.62	-3.9	-776
28.15	77.04	-79.8	-28.8	-33.88	-68.64	-14.06	-25.74	-498.58
32.0345	78.37	-513	-995.2	-263.34	-468	-80.66	-107.64	-3949.84
31.314	77.47	-61.2	-66.4	-23.1	-85.8	-14.06	-19.5	-473.36
31.342	77.582	-139.2	-20.8	-20.02	-202.8	-11.84	-7.8	-843.9
31.3	78.105	-120	-272	-79.31	-202.8	-33.3	-10.14	-1241.6
31.35	78.223	-27	-22.4	-10.01	-80.34	-3.7	-2.34	-352.11
31	78.28	-102	-26.4	-40.04	-105.3	-19.98	-7.8	-847.78
30.572	78.25	-18	-44	-29.26	-23.4	-5.18	-2.34	-366.66
30.5502	78.3336	-1.2	0	-2.31	-0.78	0	0	-19.4
30.5325	78.4012	-43.2	-38.4	-10.01	-109.2	-4.44	-2.34	-465.6
30.5325	78.433	-6	-11.2	-43.12	-6.24	-3.7	0	-355.02
30.3905	79.0135	-21	0	-38.5	-39	-7.4	0	-519.92
30.4445	79.293	-891	-17.6	-53.9	-382.2	-27.38	-14.82	-1581.1
30.4158	79.352	-4.8	-23.2	-34.65	-18.72	-7.4	-1.56	-428.74
36.325	79.313	-9	-24	-26.18	-23.4	-3.7	0	-237.65
30.36	79.481	-28.8	-11.2	-10.78	-226.2	-31.82	-3.9	-984.55
30.293	79.373	-7.2	-21.6	-32.34	-11.7	-5.92	-0.78	-349.2
30.0527	80.5313	-3	0	-4.62	-1.56	-0.74	0	-40.74
29.58	80.0856	-51.6	0	0	-62.4	-61.42	0	0
30.0853	80.2023	-7.2	-4	-49.28	-140.4	-28.12	-0.78	-834.2
29.515	80.3384	-24.6	-16.8	-30.8	-127.14	-11.1	-1.56	-494.7
34.465	77.324	-7.8	-79.2	-10.01	-105.3	-4.44	-2.184	-552.9
34.4525	77.333	-10.2	-52.8	-30.8	-93.6	-5.18	-1.56	-557.75
34.564	77.2825	-51	-45.6	-7.7	-452.4	-35.52	-6.24	-814.8
33.162	75.0345	-6.6	-1187.2	-388.08	-156	-4.44	-0.78	-2480.29
33.431	75.443	-34.8	-306.4	-130.13	-7.8	-1.48	0	-808.98
22.303	75.523	-1.8	0	-6.93	-1.56	0	0	-40.74
33.204	76.562	-18	-57.6	-10.78	-43.68	-2.96	-0.78	-227.95
33.13	78.195	-3.6	-9.6	-11.55	-7.02	-2.22	-0.702	-110.58
33.22	78.21	-4.2	-1.6	-20.79	-4.68	-1.48	-0.702	-119.31
32.421	76.0425	-357.6	-12.8	-31.57	-288.6	-22.2	-6.24	-1357.03
32.0755	76.105	-7.8	-8	-33.88	-14.82	-7.4	0	-270.63
32.071	76.431	-62.4	-4.8	-5.39	-58.5	-2.22	-0.78	-252.2
28.2	93.15	-6	-22.4	-20.79	-103.74	-7.4	0	-548.05
28.25	93.26	-92.4	-296	-97.79	-117	-12.58	0	-986.49
28.273	73.25	-21	-28.8	-41.58	-67.08	-6.66	0	-618.86

Data Set -2. Weighted Data by a weighting factor (Component loading): Peninsula

Y	X	HCO3_FSCOR	Cl_FSCOR	SO4_FSCOR	Na_FSCOR	K_FSCOR	TDS-FCOR
28.15	77.04	92.4	948.75	134.4	396	16.02	1588.5749
28.15	77.04	203.4	113.85	15.36	66	5.34	266.45
26.353	76.193	189	89.7	21.12	42	22.25	335.727
27	76.52	234	134.55	48	126	4.45	442.307
24.11	73.4118	300	96.6	3.2	78	1.78	346.385
24.13	73.424	174	34.5	3.2	18	0.89	170.528
21.4053	72.544	114	929.43	3.2	4086	48.95	0
21.4053	72.1544	246	75.9	16	57	1.78	0
22.15	72.12	90	1880.25	6.4	1140	26.7	2552.591
22.14	72.41	920.4	1675.32	430.08	700.2	129.05	3060.9776
23.4329	71.4331	117	1024.65	0	525	12.46	0
23.2	73.56	109.8	48.99	21.12	24	1.78	174.7912
19.423	72.51	7.8	3312	118.4	573	11.57	860.1006
19.4105	72.543	6.6	586.5	83.2	220.8	6.23	995.4572
19.293	73.05	8.4	834.9	92.16	234.6	7.565	1440.9616
18.04	73.27	10.8	53.82	154.88	93	1.78	300.0227
17.43	73.24	42.6	293.94	68.48	175.2	3.56	514.2485
17.15	73.33	18	258.75	64	138.6	6.942	508.9195
22.6505	81.7518	37.8	182.85	69.12	88.8	5.34	100.1852
33.1435	74.25	106.2	46.23	44.8	79.8	0	272.3119
17.55	80.4315	218.4	20.7	5.12	66	14.24	0
17.383	80.563	59.4	315.33	81.92	216	16.91	0
17.5545	80.4425	219.6	177.33	35.2	58.8	13.35	455.6295
17.56	80.43	102.6	34.5	77.184	57	6.586	258.19005
18.06	80.4	77.16	114.54	116.48	124.8	3.56	402.8724
24.09	85.41	26.4	62.1	15.36	75	2.225	293.46
23.52	87.25	180	11.04	7.68	34.2	2.67	240.17
23.4515	84.0212	72	72.45	62.72	97.2	4.45	343.1

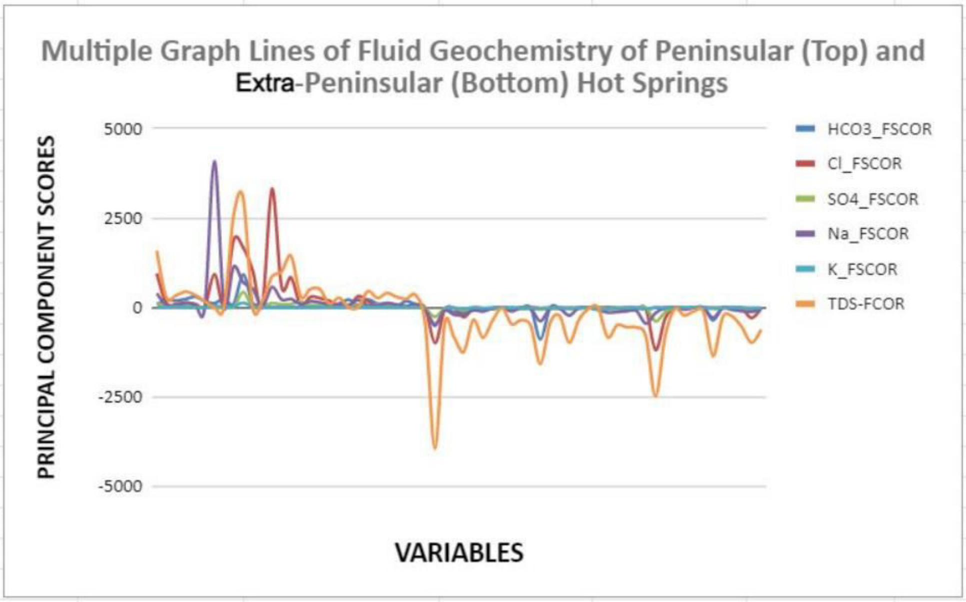
Presenting the results and Visualizing the results in a graph





III. Interpretation of the results

The two data sets, 1 and 2, have been combined to get a composite bird's-eye view of the characterization of fluid geochemistry in two tectonically diverse regions of Peninsular and Extra-Peninsular India.



TDS vs. pH

"Dissolved solids" refer to any minerals, salts, metals, cations, or anions dissolved in water. TDS stands for total dissolved solids and represents the total concentration of dissolved substances in water. The total dissolved solids concentration is the sum of the cations (positively charged) and anions (negatively charged) ions, inorganic salts, principally calcium, magnesium, potassium, sodium, bicarbonates, chlorides, and sulphates, and some small amounts of organic matter that are dissolved in water.

pH

A figure expressing the acidity or alkalinity of a solution on a logarithmic scale on which 7 is neutral, lower values are more acidic, and higher values are more alkaline. The pH is equal to log10 *c*, where *c* is the hydrogen ion concentration in moles per litre.

Though there is no direct relation between pH and TDS, carbonate, bicarbonate, and CO2 concentrations as part of TDS can affect the values of pH towards alkalinity.

An interesting feature needs be noted here.that HCO3 ions can behave either as an acid (a proton donor) or a base (a proton acceptor). Hence NaHCO3 is both an acid and a base.

$$OH^- + HCO3 \longrightarrow H_2O + CO3^{2-}$$

Bronsted base   Bronsted acid

This would explain the presence of HCO3 in the fluid geochemistry of both the Extra-Peninsular and Peninsular hot springs.

In the Factor Table, Factor F1 shows negative factor loadings for all items (Cl, SO4, Ca, Na, K, and B-TDS) in the case of Extra-Penindular hot springs, whereas for Peninsular hot springs, Factor F1 shows positive factor loadings for all items (HCO3, Cl, SO4, Na, K, and TDS), which is amply reflected in the Multiple Graph Lines of Fluid Geochemistry.

With this characteristic inverse phenomenon, the research affords a fascinating new insight into the origins of the two distinctive suites of fluid geochemistry of tectonically two diverse regions so close by yet so conspicuously distinctive.

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