BOOK REVIEW

ELEMENTS OF GEOCHEMISTRY, GEOCHEMICAL EXPLORATION AND MEDICAL GEOLOGY by K.R. Randive. Published by Research Publishing Services, Singapore. 2013, 448 p.

The book under review is an outcome of the author's desire to have a book on geochemistry that is easy to understand as well as comprehensive in approach'. The author has succeeded in his objective and should be complimented for producing such a book that covers all facets of geochemistry in a lucid and succinct manner besides including a section on 'Medical Geology' which has become an important facet of geochemistry in recent times.

The book is divided into three parts namely geochemistry (chapters 1 to 11, 228 pages), exploration geochemistry (chapters 12 to 23, 151 pages) and medical geology (Chapters 24 to 27, 65 pages) with a list of 101 references cited in the text and a subject index of 6 pages. Each chapter ends with a ***'book shelf'*** containing a list of text books for further reading.

The geochemistry part begins with basic principles of inorganic chemistry (chapter 1) such as atom, element and arrangement of elements in periodic table and their classification based on atomic radius, electron affinity, ionization energy and electro negativity. Mineral chemistry (chapter 2) deals with the chemistry of minerals in terms of crystal chemistry, silicate structures, atomic and ionic substitution, solid solutions and iso-morphism, poly-morphism and psedo-morphism. The phase rule, mineral equilibrium and laws of thermodynamics are dealt with in a simple way so as to provide a sound basic understanding of the chemical principles that underlie processes in geochemistry. Geochemistry of major elements (chapter 3) covers those elements which forms the bulk of the rock and minerals and how a major and minor oxide analysis, given in weight percentages is converted in to atomic weight, molecular weight, gram formula weight, gram equivalent weight and the mole. Calculation of mineral formula for silicate minerals are provided besides the computation of CIPW and molecular norms are given with worked examples. Examples of bi-variant and triangular diagrams are shown which help in the classification of rocks as also in deciphering the major and minor oxide variation during their petrogenesis. Trace element geochemistry (chapter 4) deals with the Goldschmidt's rules of distribution of trace elements, trace element substitution and the partition or distribution coefficient of elements in different minerals and the rock with examples. The role of trace elements and geochemical processes are provided using the traditional groupings such as LILE (Rb, Ba, Th, U, Ta, and the light REE), alkali metals (Li, Na, K, Rb, and Cs), alkaline earth metals (Be, Mg, Ca, Ba, Sr), high field strength elements (HFSE: Nb, Ta, Ti, Zr, Hf), PGE (Ru, Rh, Pd, Os, Ir, Pt) and REE (La-Lu, Sc, Y). Presentation of trace element data in terms of bivariate and multivariate diagrams besides element ratio plots, enrichment-depletion diagrams and vector diagrams are given besides data on the numerous normalization factors such as the MORB, primitive mantle and the chondrites 1 and 2. Aspects on interpretation of the data on such diagrams are provided. Isotope geochemistry (chapter 5) deals with definitions, standards etc., of both stable and unstable (radiogenic) isotopes, and their use in both geochronology and inferring various petrogenetic processes including mantle and crustal sources.

Geochemistry of the universe (chapter 6) provides a brief account of the universe and its formation through big bang, formation of stars, galaxies and the solar system, the sun, asteroids and different types of meteorites, the moon, cosmic abundance of elements and the origin of elements through both primordial and stellar nucleosynthesis. This chapter could have been placed in the beginning so as to form the basis on which the geochemistry edifice has been built. Geochemistry of the earth (chapter 7) deals with the internal structure of the earth and the various constituent units, the major element composition of the crust estimated by different workers based on different assumptions, Clarke and concentration Clarke which provides a measure of ore level concentrations needed to form an ore body. Estimates for the composition of the earth as a whole are also provided. Brief accounts of the primary differentiation of the elements during earth's formation are also included along with Goldschmidt's classification of elements.

Geochemistry igneous rocks (chapter 8) begins with definition of magma and its composition followed by the classification of igneous rocks based on major and minor oxides and their mineralogy. The operation of specific igneous processes to explain rock diversity has been demonstrated with the help of appropriate bivariate plots beginning with the melting of source rocks followed by

crystal fractionation, mixing of magmas, assimilation and/or contamination by country rocks and liquid immiscibility.

Geochemistry of metamorphic rocks (chapter 9) defines metamorphism, its grades and facies, metamorphic minerals and their compositions. Geochemical variations have been elucidated using the traditional ACF, AKF diagrams and the more appropriate 4-component AFM diagram along with simple computational details that enables a better understanding by the students. Aspects on metamorphic reactions, both univariant and divariant have been covered followed by a section on role of fluids and metasomatism including those of crustal and mantle rocks besides those pertaining to ore deposits.

Geochemistry of sedimentary rocks (chapter 10) begins with a description of sediments and sedimentation followed by their compositional diversity, classification and mineralogy. This is followed by a major section that deals with physico-chemical factors that govern the sedimentary processes such as ionic potential, hydrogen ion concentration and redox potential, Eh-pH, adsorption and colloid formation. The final section on geochemistry of sedimentary processes provides examples of major oxide bivariate plots to infer paleo-tectonic settings of sandstones. The use of trace elements such as Th-Sc-La and Sc-Th-Zr/10 to infer tectonic regimes has also been included. The inference on the chemical composition of provenance rocks has been demonstrated using discriminant functions involving major components of sedimentary rocks. The chapter concludes with a brief section on chemical changes during weathering inferred from major and trace elements, transportation and diagenesis. Geochemistry of ore deposits (chapter 11) forms an appropriate opening for the next section dealing with geochemical exploration and deals with basic aspects on ore, gangue, processes of ore genesis and classification of ore deposits. This is followed by a major section that deals with the geochemistry of ore forming processes during the formation of magmatic, hydrothermal, volcanogenic massive sulphide and skarn deposits. Further importance of fluid inclusion and stable isotope studies and exploration guides are also provided. The chapter ends with description of ore enrichment due to weathering and oxidation and supergene sulphide enrichment.

Chapter 12 on geochemical exploration describes briefly the whole gamut of geochemical exploration beginning with a definition and terminologies such as background, geochemical relief, threshold and anomaly both positive and negative. This is followed by description of the ten types of geochemical surveys that are carried out depending upon the geochemical environment and the nature of geochemical dispersion expected from a particular type of deposit. This is followed by a brief account on the mobility of elements and geochemical association of elements such as K-Rb, Ca-Sr, Al-Ga, Si-Ge, Zr-Hf, Zn-Cd, S-Se, U-Th, REE and PGE in magmatic deposit which may be changed due to surficial processes. Brief account on indicator and path finder elements is is provided along with a table summarizing important path finder elements and related ore deposits. The chapter ends with a brief outline on geochemical mapping, type of geochemical maps and the symbols used therein.

Dispersion pattern of deep seated origin manifested from both syngenetic (primary) and epigenetic (mainly hydrothermal) deposits are described in chapter 13 along with concepts on geochemical and metallogenic provinces. Wall-rock alteration, a common feature of epigenetic deposits, along with their depth- and distance-wise classification into epi-, meso- and hypothermal alteration zones are also dealt in addition to the leakage anomalies that ensue from different types of ore bodies and the prevalent structure. The chapter ends with brief outlines on compositional zoning of ore bodies, dispersion effects on epigenetic minerals due to P-T effects and geothermometry.

Surficial dispersion patterns (chapter 14) includes weathering processes, soil formation, soil profiles and the soil classification (12 types). Dispersion processes and their patterns and their classification are also detailed ending with details on anomalies of both in situ (residual, eg. gossans) and transported types. Methods of sampling (chapter 15), described in sufficient details, the principles of sampling, size of samples, and various methods of sampling such as chip, grab, channel and random sampling and sub-sampling that are required for quality assurance and taking up different analytical procedures for different elements. Quality assurance including quality control of the analysis such as precision, accuracy of the analysis and other best practices that are needed in a geochemical exploration program are also dealt with. Sample preparation (chapter 16) begins with the whole gamut of laboratory techniques and instrumentation (crushers, grinders, ball mill and pulverizer) that are needed to establish a sample preparation laboratory. Separation and concentration techniques normally adopted in good laboratories are outlined. Sample dividers of both manual (cone and quartering) and mechanical types (riffle and rotary types) are also described. The chapter ends with an important note on sample homegenisation and the 21 sources of sample contamination that needs to be avoided in any robust geochemical exploration programme. Laboratory methods of analysis (chapter 17) deals initially with certain basic aspects like the criteria for choosing a particular method of analysis beside accuracy, precision, systematic and random errors, sensitivity, detection limits

and others that influence a given analysis by a specific method.

This is followed by brief details on some separation techniques (ion exchange, fire assay, selective sample dissolution) followed by brief outlines of the different instrument methods of analysis such as AAS, XRF, INAA, ICP-AES/OES, ICP-MS, TIMS besides brief mention of other techniques like accelerator mass spectrometry, alpha spectrometry, gas source MS, Ar-Ar mass spectrometry, SIMS, PIXE, laser ablation ICP-MS and X-ray microprobe.

Chapters 18 to 20 deal with various methods of geochemical surveys such as bed rock, soil and stream sediment respectively. Details provided include the principles, methodology, orientation survey and detailed follow up surveys. They also include details on sample collection, their preparation, map preparation based on elemental abundances and interpretations. Biogeochemical and geobotanical surveys (chapter 21) include the basic principles involved followed by an account of the availability of trace elements, the nutritive requirements of plants and the modes of transportation of these to the different parts of the plant during its metabolism. The methodology adopted in the surveys including orientation, detailed follow up and interpretation of data are also provided. The details on geobotonical surveys include the details on indicator plants for specific deposits, ores and rock types besides the routine modes of orientation and detailed surveys followed by interpretation. Other geochemical surveying methods (chapter 22) includes surveys that are specific to certain deposits like atmospheric Hg for sulphide deposits, radon in soil, air and atmosphere for radioactive deposits with U and Th. Lake sediment surveys and hydrogeochemical surveys using U, Mo, phosphates temperature, eH, pH and others are used for seeking buried or deposits located in the provenance areas are also briefly given. Design of geochemical exploration programs (chapter 23) begins with an outline of prospecting vs exploration and elucidates important aspects such as the viability of the exploration program, the role of the geologist vs geochemist and planning and executing the program that involves numerous steps including viability, coordination and supervision besides technical aspects.

The section on Medical Geology chapter 24 deals with principles and history of medical geology, wherein, medical geology is defined along with the role of medical geologist and the geomedical cycle involving the transport of elements from rocks to the human body. Geological sources of health hazards, both of natural and anthropogenic origin including mining activity are included. The subject of geopharmacy is briefly outlined besides historical aspects on health hazards recognized over 7000 years ago from Alaska and the recent interest by IUGS in the subject through creation of Working Groups on Environmental geoindicators and medical geology. Trace element and human health (chapter 25) begins with the importance of trace elements, required in mg or micro-gram quantities, such as Ca, Cr, Co, Cu, Fe, Mg, Mn, Mo, P, K, Se, S and Zn along with recommended dietary allowances (RDA). The chapter deals further in sufficient detail on the toxic elements, their entry and transport in the human body, storage and excretion besides the diseases caused from such element toxicity. Geological health hazards (chapter 26) details further the scope of health hazards due to excessive and deficient intake of certain elements such as Hg, Cd, F, Pb, As and others including those from mining activities. Health hazards due to natural disasters such as volcanic eruptions, earthquakes, tsunamis and the resulting environmental stress are also dealt within this chapter. Mineral medicines in Ayurveda (chapter 27) provides a comprehensive account of geological materials such as minerals, metals, gemstones, semiprecious stones, and a variety of Ca-sources including fossils that were used for medicinal purposes in the '***Rasashastra***', a branch of Ayurveda, the ancient Indian tradition of medicine. This chapter also provides an account of the literature on *Rasashastra* and concludes with a list of medicines made with a base of mercury.

Thus the book provides a simple, succinct and lucid account of the entire gamut of geochemistry, exploration geochemistry and the new branch of medical geology.

The book is an excellent addition to such texts already in the market. However, it is very student-friendly since it provides details on varied topics covered under its title in a more focused, succinct and straight forward manner that it becomes like a guide book. The author must be complimented for his efforts. The book has been elegantly produced by the Research Publishing Services, Singapore with neat layout the text, figures and tables. Considering its size and contents, the book is almost error free except for some non-capitalizing of some author's name in the text or references and one diagram (Fig.8.8, p.159) in which the arrows indicating the % fractionation should have been proper.

Furthermore, the most revered doyen of Indian geology, the late B. P. Radhakrishna had blessed the author in his endeavour to write a book on this topic. The book must adorn the shelves of libraries as a book of reference and thus will be useful for both geologists and non-geologists alike.

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