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CONTENTS

POSITION PAPER ON INSTITUTE OF GEOLOGY, UNIVERSITY OF THE PUNJAB

BY

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HISTORY OF DEVELOPMENT

1. Not a single school of geological learning was located in the part of British India that formed the present State of Pakisthn in 1947. The newly created country, therefore, inherited no academic establishment to produce geologists and related scientists. Only a few Muslim geologists from the (British) Geological Survey of India opted and formed nucleus of the Pakistan Geological Survey, but no person with teaching experience became available It is notable that at the time of Independence, adequate geological information was available only of 28% of regions of Pakistan so that a large number of geologists were required urgently to explore natural resources for economic development of the new country.

2. The initiative was taken by the Punjab University and a Department of Geology was opened in 1951 in the Geography Department, under the aegis of (Late) Dr. Kazi Saeed-ud-Din, Professor and Head of the Department. The new Department srarted to impart teaching of geology in September, 1951, at the Intermediate Science (F. Sc.) level as an elective subject (This course was dropped by 1953).

3. In view of national urgency to develop mineral resources of the country, the Punjab University also opened in 1952 in the Institute of Chemistry an independent Department of Mineralogy under a Unesco-Pak Government protocol ; Professor O. A. Broch, Norway, arrived in April, 1952, as Head of the Department. This Department offered a course for specialization in Mineral Chemistry for the M. Sc. Final year students (This course was discontinued by 1953).

4. In January, 1954, the two departments were combined into the Department of Geology and Mineralogy, under Professor O. A. Broch, and was housed in the (Old) U.O.T.C. building which is now occupied by the University Clinic and the Habib Bank at the Old Campus. The first B. Sc. class in geology was held under the integrated Department.

5. In 1954, the Government of Pakistan requested Unesco to provide an Adviser in Petroleum Geology and Professor N.R. Martin, U.K, took over in December, 1955, from Professor O.A Broch as Head of Department. The first M.Sc. class in geology was produced in 1957 in the specialized field of Petroleum Geology.

6. A new Unesco Adviser arrived during late 1956 to further develop the Mineralogy Project and a Unesco expert arrived for 3 months to train local personnel in geological workshop techniques By the end of 1958, a Unesco Adviser arrived to establish teaching of Geophysics and another Adviser in the field of Palaeontology and Stratigraphy.

7. By 1958, it was planned to build the Department in such a manner as to impart a balanced geological background in various major disciplines of the subject so that the

word "Mineralogy" was dropped from title of the Department, and called the Department of Geology, incorporating :—

1. Section of Palaeontology and Historical Geology.
2. Section of Mineralogy and Petrology.
3. Section of Petroleum Geology.
4. Section of Geophysics.

8. The Unesco Technical Assistance Mission spent a total of 19.33 expert years and concluded in May, 1962. The names of Unesco experts and periods spent are given in Table 1.

9. Before conclusion of the Unesco Mission, steps were taken to invite another expatriate, Dr. R. G. Davies, U. K., who was appointed Professor of Geology in September, 1961, and took over as Head of the Department in April, 1962 ; his appointment was subsidized by Leverhulme Trust, U. K. Dr. Davies left in June, 1967 and Mr. F.A. Shams was appointed as the first Pakistani Head of the Department ; continued till December 1972, when the system of rotation of Headship was introduced under the new University Act to be designated as Chairman of the Department. Names and tenures of Heads and Chairmen of the Department are given in Table 2.

10. During the period 1965-68, two more Sections were established :—

1. Section of Geochemistry and Research.
2. Section of Engineering Geology and Geohydrology.

11. In Summer, 1965, the Department was shifted from the Old Campus to the New Campus into a building which was planned to suite academic and administrative plan of the Department. This resulted into considerable expansion of space with each section having its own integrated staff rooms and laboratories.

12. By summer, 1978, B.Sc. Chemistry Laboratory at the New Campus was taken over from the Institute of Chemistry, housed in a big hall, with two attached rooms, at the ground floor of the Geography-Statistics Block. In a way, this meant further expansion of the Department. Similarly, the B. Sc. Physics Laboratory at the New Campus is to be taken over from the Department of Physics to complete a major phase of development.

13. An unique programme at the New Campus had been to establislish the first ever Palaeomagnetism Laboratory of the country. With generous financial help from the University, a Hut for the purpose was constructed near the V.C. House. It was especially designed and built with non-magnetic construction material. The Hut was completed in 1962.

The difficulty of buying/importing instruments for the Hut during the post-1965 war period was solved through free donation by the Australian National University, Canberra, Australia. A senior staff member was sent to Canberra for training in this highly specialized field. The project, however, could not take off well due to leaving abroad of the staff member concerned in 1973. Later, havoc was played with the Hut by a severe storm during summer, 1974, which blew up roof of the Hut and smashed its walls. The laboratory is very much wanted in the country.

14. On Augnst, 1979, the Department was elevated to the status of Institute of Geology and Professor F.A. Shams was appointed as the first Director.

The Institute

The Institute comprises 3 Divisions :—

1. Division of Economic Geology :	Dealing with subjects concerned with minerals ores and rocks.
2. Divison of Petroleum Geology.	Dealing with subjects concerned with natural hydrocarbons.

3. Division of Applied Geosciences. Dealing with subjects that are employed in search of natural resources including water and the construction of engineering works.

Each Division integrates two related Sections of the (previous) departmental set-up. Thus, administrative and academic bias was shifted more to professional and applied nature. This was adopted as a policy for generating a scheme of studies, leading to 4-years B. Sc. (Applied Geology) and 1-year M. Sc (Applied Geology). This was prompted due to following reasons :—

1. There is increased stress on the exploration and development of country's hydrocarbon, industrial mineral and rock and water resources.
2. There is an ever-increasing number of projects for the construction of dams, heavy engineering complexes, mills and super highways.
3. There is an urgency to develop surface and ground water due to development in sofar neglected areas and for increasing the volume of agricultural produce.
4. There are not many agencies in the country that employ geologists for basic research while most of the new agencies are developed in the applied geologic field.
5. There is an unprecedented expansion in the private sector, both for investigation and development activities.
6. Many new subjects and disciplines have developed in the world that require urgent incorporation in the geology curricula.

To meet the above challenges, academic planning had to be so oriented that students develop a strong background at the B. Sc. level and only then specialize at the M. Sc. level. In this way, the student will be able to work for higher degrees as well as being capable of handling any sort of geological project with multidisciplinary facets.

Otherwise too, a rather latent weakness of the old scheme of studies has been the large number of failures in allied science subjects rather than in geology. Due to its fixed weightage, the old scheme also had no flexibility to introduce new topics, while the scientific world was advancing rapidly. This could be done by trimming allied subjects at the first 2-years period and adding new courses of geology in place. This would ensure much stronger specialization at the M. Sc. level than the old scheme. In the new scheme, therefore, followings were included as major steps :—

1. Field work was given higher weightage and is so introduced right from the Ist year. In the 4th year supervised field work is required for atleast 2 moths, on an allotted research problem, to produce Field Report.
2. At the M. Sc. Stage, recognisable independent research is expected froma student in the form of a Thesis.
3. The University examination is held each year to sub-divide academic load and to create a progression in the studies.

Many new topics have been added, such as.

(i) Sub-surface mapping techniques.
(ii) Applied laboratory techniques.
(iii) Resource Evaluation and Development Economics.
(iv) Mining Geology.
(v) Nuclear Geology and Geothermal Energy.
(vi) Statistical geology.
(vii) Mineral Technology and Grade Control.

Details of the scheme and the philosophy behind is given in the prospectus of the Institute of Geology. It is heartening that most of the leading geoscientific agencies of the country have supported the scheme. The author had the chance to present it in the 26th International Geological Congress, Paris, 1980, where it received considerable support and was recognised as a useful model for the developing countries of the world. At present students of the 3rd year class of the new scheme are on rolls. Graduates of the Institute under the older scheme have made their mark within the country and abroad. Out of the 653 geologists produced till 1981, many have risen to high academic and professional positions. Fig. 1, gives a graphical representation of variation in student population over the period 1951-81. This includes students from many countries of Middle East, Africa and Asia.

TRAINING AND RESEARCH FACILITIES

1. Laboratories

The Institute has student laboratories in all major subjects while there are many research laboratories that are used both by students and teachers for research. These are :—

1. Advanced petrographic Lab.
2. Mineralgraphic Lab.
3. X-Ray Diffraction Lab.
4. Engineering Geology Lab.
5. Photogeology Lab.
6. Mineral Separation Lab.
7. Geochemistry Lab.
8. Geophysical Lab.
9. Advanced Palaeontology Lab.
10. Photographic Lab.

There are mechanical, rock cutting and thin sectioning, ore mounting and polishing workshops as essential aids to support academic and research activities.

2. Library

As a sectional library, it is rich with literature containing books, 6,000 and a few thousand reprints of research articles. Many unique publications are available such as HMS Challenger Reports, Italian Expedition Reports, Records and Memoirs of (old) Geological Survey of India, Japanese Expedition Reports, Catalogues of Foraminifera and Ostrocoda etc. An unique set of geological literature consists of M. Sc. and Ph. D. thesis and Field Reports of Internal origin, with volumes of new maps and original geological data. Those now available in the library are listed in the circular publication. Although many international journals are received under exchange programme yet such literature is becoming poorly available in the library due to paucity of funds.

3. Museum of Geology

As a store-house of geological and related specimens, the Museum of Geology offers unique assistance in training and research programmes. Thousands of natural specimens are available from almost all parts of the world, including Antarctica. Meteorites, gemstones, Vertebrate fossils, energy source raw materials are among some special additions. Displays are given of indigeneous industrial raw material and the corresponding finished products. Decorative and building stones are displayed alongwith minerals, rocks and fossils from Pakistan. A visit to the Museum is very much requested.

4. Field Work Facilities

Transport, tentage and field work equipment is available in reasonable number and this essential activity could be always undertaken in any part of the country. As no separate allocation of funds is made for staff research, teachers have to cary out their field work while supervising M. Sc. research projects. Ignoring minor drawbacks, this system ensures teacher-student relationship, guidance and data checking on locationand continued research activity of the teachers. As a result, volumes of new geological and geophysical maps have been produced and a study flow of publications has been possible by faculty of the Institute.

In addition, independent staff research is undertaken as part of expeditions and joint projects with other agencies. Results of Baltistan Expedition, Aug/Sept. 1982, will be presented separately Fig, 2 shows such areas of the country that have been covered during field work and on which publications have been made, in addition to preparation of large-scale maps.

Many of the maps and discoveries made during field work have been instrumental in generating national and international research activities.

MAJOR RESEARCH CONTRIBUTIONS

1. Staff and students of the Department (now Institute) started producing research right from early fiftees ; for instance the very first publication appeared in 1955 (F.A. Shams). The real breakthrough came in 1959-60, when sufficient equipment and transport became available for field work. The volume of data thus produced justified issuance of our own research journal, the Geological Bulletin, due also to the absence of any geological periodical in the country. Soon it received recognition and started attracting articles from foreign scientists as well. So far 16 numbers of the Geological Bulletin have been published and its Centenary Number is in press at present. So far 155 papers have been published and one Special Supplement. In addition, contributions are made also to national and international journals. The full list of publications till 1983 is given in a publication including Books written by staff of the Institute. While details of research achievements are being published as part of a book on Biography of the Institute, some of the highlights are given herewith :—

1. The detailed revision of Hazara sedimentary and crystalline regions, after a lapse of about 70 years, not only produced new geological maps but also many revolutionary concepts regarding stratigraphy and origin of lithologic formations of the region. This had considerable implications.
2. Production of first-ever geological map of the Swat District (1962) not only filled a blank spot on the Geological map of Pakistan but also generated programmes of detailed work on acidic and basic complexes of the region, thus, establishing multiplicity of igneous activity and variety of processes acting on regional scale to show the chronological order of formation and emplacement of rocks.
3. Discovery of alkaline rock province in Lower Swat not only came as the first example in the N. W. Himalayas but also established possibility of such occurrences in alpine orogenic belt, that was previously denied universally. The discovery of carbonatites in Lower Swat led to further discoveries of alkaline and related igneous intrusions in the Vale of Peshawar.
4. The discovery (1971) of blueschist metamorphism in Shang-La area, Swat District, opened possibilities for the application of concepts of plate tectonics to the Himalayas Karakorum and Hindukush. This has strong bearing on exploring regimes of mineralization, metamorphism, igneous activity and of geotectonic evolution. This work was extended to Gilgit-Hunza and Baltistan with valuable results.
5. Discovery of new fossil localities, some time in claimed non-fossiliferous rock formations, contributed greatly to stratigraphy of Pakistan with multifareous implications.

6. The discovery (1954) of uranium minerals in the Indus river sand at Darband and Chilas, gave rise to extensive activity for uranium prospecting in the country that is still yielding recongnisable results.

7. The application of geochemical techniques to the igneous-metamorphic complexes of Pakistan helped in establishing their genetic history long before the foreign researchers started to apply most modern techniques; they simply confirmed the earlier conclusions.

8. The geophysical investigations in the Mansehra and Swat regions established sheet-like configuration of the granite bodies and plutonic nature of the younger intrusions. This not only confirmed the geological work by producing 3-dimensional models but also assisted in understanding their role in the tectonics of the Himalayas.

9. Discovery of many new mineral deposits, so far unknown, has brought considerable reputation to the Institute.

In this connections, it is worthwhile stating that this Institute has made important contribution by establishing the skill of Pakistanis in organising regional expeditions. The very first was held in northern Pakistan during 1974, before the major Royal Geographical Society venture of 1980. Similarly, another expedition was organised during August-September, 1982 in Baltistan, a region occupying the remote NE part of Pakistan. Previously, a Unesco expert organised an international expedition to K12 and made valuable contributions. Close liaison is kept otherwise with most of the international mountaineering and expedition-oriented institutions. It was due to such reputation that writer could receive 22 papers from 10 countries of the world, as part of a book on Granites of Himalaya, Karakorum and Hindukush; this is being published as part of Centenary Celebration of the Punjab University.

FUTURE PLANS

The Institute is faced with unique challenge of establishing a suitable base for the success of new academic scheme, aimed at producing professional geologists. Due to main bias of the scheme being applied geology, new laboratories, new instruments and more staff positions are urgently needed to cope with the new courses of training. Our major aim, therefore, is to modernise and partly re-equip laboratories of the Institute so that new laboratories will be added wherever necessary. There will be yet an higher stress on field training while most of the research will be undertaken in the applied field. Training will be more in practical techniques based on concepts of applied nature so that the student, after leaving the Institute, may take up any type of geological job with enough confidence. Some of the salient features of our future plans are:—

1. Consolidation of academic programmes with constant consultation with expertise in other academic and development agencies. Efforts will be made to further strengthen instrument-oriented training.

2. A new factor will be introduced to initiate research projects of economic significance, in addition to pure research. One of the major projects will be a systematic investigation of small to medium sized mineral deposits that mostly remain neglected. Considerable benefits can be drawn by way of small scale industries, as most of these are located in regions with adequate infrastructure. The research will aim at producing preliminary technical reports and research papers that may emerge. Such reports and papers can become basis of feasibility studies for actual utilization of resources. Another area of future research is that of rare and trace elements, such as *Zirconium*, *Osmium*, *Iridium*, *Lithium*, *Molybdenum*, *Cerium*, *Beryllium*, *rare*

earths etc. Showings of these elements are already known while favourable geological conditions occur to justify regular work. No private agency will risk capital for this class of elements, while public sector agencies lack technical infrastructure for such a specialized task ; this job can be taken-up best by a research institution; in fact it must be taken up due to future industrial requirements of the country. For regional geological research, a major programme concerns the Salt Range due to its unique geological history and treasures of useful resources. It is planned to build a Field Station somewhere in the Salt Range for launching field programmes and operating it as an excursion base. It is hoped that such a project will give rise to country's first Field Museum of Geology. Major programme of geophysical research will concern seismic surveys that have attained importance after advent of concepts of plate tectonics. This and other geophysical work will concern directly or indirectly with indigenous natural resources. The engineering geological research will concern mostly with slope problems, in addition to traditional work on specific aspects of damsites and groundwater investigations. In the field of geochemistry, systematic work will be undertaken on individual rock complexes ultimately preparing regional geochemical maps and perfecting techniques.

For the success of above and many more programmes, collaboration with national and international agencies will be further strengthened but provision of adequate equipment and staff positions only can ensure better outcome.

On behalf of faculty of the Institute, I must put on record that in our unique endeavour to establish the Institute and to introduce new scheme of studies, our present Vice-Chancellor, Dr. K. M. Ibne Rasa, has been a source of encouragement and that his official help has been always available. I also thank the Geological Survey of Pakistan, Oil and Gas Development Corporation, Pakistan Mineral Development Corporation, Pakistan Atomic Energy Minerals Centre, WAPDA, NESPAK, Punjab Mineral Development Corporation, Ministry of Petroleum and Natural Resources, University Grants Commission, Pakistan Science Foundation, P.C.S.I.R. and many other agencies and individuals who have helped us in many ways.

TABLE 1

The Geological Bulletin, Punjab University Publication Data

Year	Number	Major Papers	Short Papers	Total	Grand Total
1961	1	7	3	10	10
1962	2	4	6	10	20
1963	3	4	5	9	29
1964	4	4	4	8	37
1965	5	4	3	7	44
1967	6	6	3	9	53
1969	7	5	3	8	61
1971	8	5	2	7	68
1972	9	8	3	11	79
1974	10	6	2	8	87
1974	11	9	4	13	100
1976	12	9	2	11	111
1976	13	5	2	7	118
1977	14	8	3	11	129
1978	15	8	3	11	140
1981	16	15	2	17	157

TABLE 2

Tenure of Heads, Chairmen and Directors of Department/Institute of Geology, Punjab, University

Sr. No.	Name	Designation	Country of Nationality	Qualification	Subject	Period
1	K S. Ahmad	Head of Department.	Pakistani	M. Sc. (Alig.) Ph. D. (London)	Geography	(Department of Geology Sep. 1951—Jan. 1954.)
2	O A. Broch	"	Norway	N. A.	Mineralogy	(Department of Mineralogy) April, 1952—Dec. 1953. (Department of Geology and Mineralogy). Jan. 1954—Dec. 1955.
3	N. R. Martin	"	U. K.	M. Sc. Ph. D (London) A.K.C., F G. S.	Petroleum Geology Structure.	(Department of Geology and Mineralogy). Dec. 1955—May, 1958. (Department of Geology). June, 1958—April, 1962.
4	R. G. Davies	"	U. K.	M. Sc. Ph. D. (Wales) F.R.I.C.	Min/Pet, Photo-geology Economic Geology.	April, 1962—June, 1967.
5	F. A. Shams	"	Pakistani	M. Sc (Pb.) Ph. D. (Pb) M. A., (Cantab).	Mineralogy/Petrology.	June, 1967—Dec. 1972.
6	M. A. Latif	Chairman of Department.	"	M. Sc. (Pb.) Ph. D., D. I C., (London) F. P. T. C (Vienna).	Micropalaeontology/ Stratigraphy.	Jan. 1973—Dec. 1974.
7	A. H. Gardezi	"	"	M. Sc. (Pb.) M. Sc, D. I. C. (London) D M. (E. N.I.) Rome.	Petroleum Geology/Structure.	Jan. 1975 October, 1975.
8	M. Ghazanfar	"	"	M, Sc. (Pb.), M. Sc. (Sheffield)	Applied Geomorphology.	November, 1975—October, 1977.
9	F. A. Shams	"/Director	"	As above	As above	November, 977—October, 1979.
10	M. A. Latif	Director	"	As above	As above	November, 1979—Dec. 1980.
11	F. A. Shams	Director	"	As above	Aa above	January, 1981—

TABLE 3

List of Unesco Experts Who Served in the Department

Sr. No.	Name	Country	Subject	Period
1	O. A. Broch	Norway	Mineralogy	April, 1952—December, 1955.
2	N. R. Martin	U. K.	Petroleum Geology	October, 1955—May, 1962.
3	E. O. Rowland	U. K.	Lab. Technician	October, 1956—December, 1956.
4	G. Zeschke	Germany	Mineralogy	December, 1956—October, 1958.
5	P. J. Stephenson	Australia	Mineralogy	December, 1958—May, 1960.
6	K. Helbig	Germany	Geophysics	December, 1958—May, 1960 January, 1961—April, 1961 March, 1962—April, 1962
7	P. Marks	Netherlands	Palaeontology	December, 1958,—May, 1962.

TEACHING STAFF ON 31-10-1982

Professors 3 :

1. Dr. F.A. Shams,
   M.A. (Cantab), M.Sc., Ph. D. (Pb.),
   Directer of Institute.
2. Dr. M.A. Latif,
   M.Sc. (Pb.), F.P.T.C. (Vienna),
   M.Sc., Ph. D., D.I.C. (London).
3. Vacant.

Associate Professors 3 :

1. Dr. Shafeeq Ahmad,
   M.Sc. (Pb.), Ph. D. (Pb.).
2. Dr. M. Nawaz Chaudhry,
   M.Sc. (Pb.), Ph. D. (London).
3. Vacant.

Assisstant Professors 9 :

1. Mr. Munir Ghazanfar,
   M.Sc., M.A. (Pb.), M.Sc. (Sheffield)
2. Mr. Muhammad Hussain Malik,
   M.Sc. (Pb.), M.Sc., D.I.C. (London).
3. Dr. Abdul Shakoor,
   M.Sc. (Pb.), M Sc. (Leeds),
   M. Sc. (Purdue) Ph. D. (Purdue).
4. M. Zulfiqar Ahmed,
   M.Sc. (Pb.). P.D.M.P. (Leoben).
5. Mr. Hamid Masood,
   M.Sc. (Pb.).
6. Mr. Aftab Mahmood,
   M.Sc. (Pb.).
7. Mr. Umar Farooq,
   M.Sc. (Pb.).
8. Mr. Zahid Karim Khan,
   M.Sc (Pb.).
9. Mr. Riaz Ahmad Sheikh,
   M.Sc, (Pb.).

Lecturers 5 :

1. Mr. Iftikhar Hussain Baloch,
   M.Sc. (Pb.).
2. Ch. Nazir Ahmad,
   M.Sc. (Pb.).
3. Mr. Akhtar Ali Saleemi,
   M.Sc. (Pb.).

4-5. Vacant.

Research Officer :

1. Syed Aleem Ahmad Shah,
   M.Sc. (Pb.).

NON TEACHING STAFF

Chief Technician :

Mr. A. Z. Dean

Librarian 1 :

Mr. Khurshid Ahmad.

Geological Illustrator : 1 (Vacant)

Senior Stenographer 1 :

Mr. Muhammad Riaz.

Assistant 1 :

Mr. Faqir Ahmad.

Draftsman 1 :

Mr. Masood Minhas.

Jr. Technicians 3 :

1. Mr. Abdur Rauf.
2. Mr. Zafarullah Butt.
3. Vacant.

Jr. Stenographer 1 :

Mr. Muhammad Arif Jr. Clerk (being charged against this post).

Senior Clerk 3 :

1. Muhammad Iqbal (on leave)
2. Mr. Ghulam Mohyuddin.
3. Mr. Masood Ahmad Lodhi.

Head Lab. Assistant 1 :

Mr. Rafiq Ahmad.

Storekeeper 1 :

Mr. Muhammad Yaseen.

Sr. Lab. Assistants 3 :

1. Mr. Muhammad Afzal.
2. Mr. Manzoor Hussain Shah (appointed as Junior Lab. Assistant against the vacant post).
3. Vacant.

Junior Clerk-cum-typist 1 :

1. Mr. Muhammad Hafeez.

Junior Clerk (Library) 1 :

Mr. Muhammad Suleman.

Drivers 2 :

1. Mr. Taj Muhammad.
2. Vacant.

Junior Lab. Assistants 3 :

1. Mr. Ehsanullah Khan.
2. Mr. Muhammad Latif.
3. Mr. Mukhtar Hassan Shah.

Museum Attendent 1 :

Mr. Muhammad Younas.

Junior Lab. Attendent 3 :

1. Mr. Abbas Masih.
2. Mr. Liaquat Ali s/o Ilam Din.
3. Vacant.

Library Attendent 1 :

Mr. Nazir Ahmad

Naib Qasideen 2 :

1. Mr. Liaquat Ali son of Barkat Ali.
2. Mr. Muhammad Ashraf.

Cooli 1 :

Mr. Barkat Ali.

SAFETY IN THE SERVICE OF MINERAL OPERATORS IN PAKISTAN

BY

RANA MUHAMMAD SULTAN

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Abstract : *The long awaited rescue service has been introduced in Pakistan and in consequence to that 2 min-s rescue and safety stations have been established one, at Sinjidi (Baluchistan) the second at Khushab (Punjab). Additional substations are also being established. This will repose confidence in the minds of local population to adopt mining as profession.*

Mineral operators mean all those persons who are working in and about the mines and quarries, be they workers, supervisors, geologists or engineers.

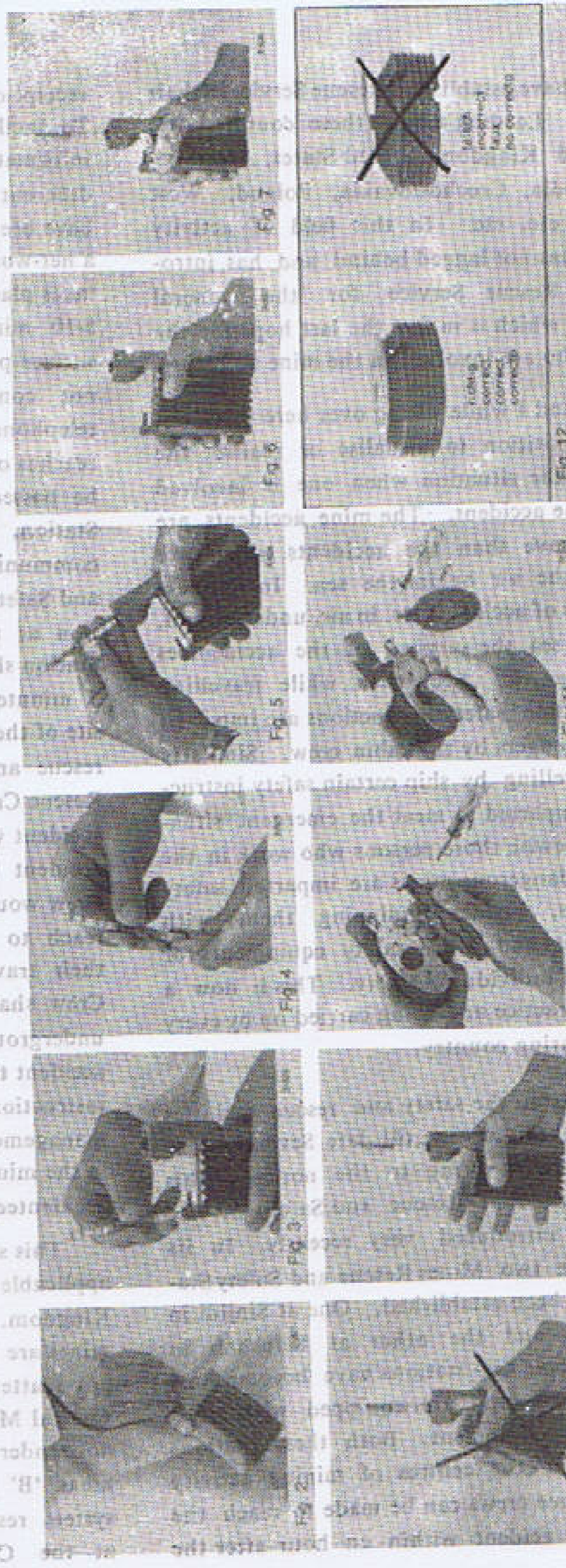
Prior to 1970 safety in mines used to confine to the inspection of mines by the Inspectors of Mines in accordance with the provisions of Mines Act, 1923, rules and regulations made thereunder. The tools which used to be operated upon were flame safety lamp to detect various gases present in the mines and small birds such as canneries for the detection of poisonous gases in the mines. Although the inspecting officers had always been qualified, competent Mining Engineers having a lot of field experience at their credit but the fact remains that the methodology which used to be adopted for the detection of gases was old and un-scientific.

In early Seventies the concept of scientific and systematic means was introduced to detect gases. Detection tubes were introduced which are being manufactured by one of the world-renowned companies by the name DRAGAR from West Germany.

These tubes facilitate to detect Carbondioxide, Carbonmonoxide, Methane, Hydrogen Sulphide, Nitrogeneous Fumes present in the mines. The device through which these gases can be detected is known as Multi-gas Detector. This device is handy and can be used by persons of even ordinary prudence working at the mines.

By the introduction of this detection system it can be said that modern and scientific approach has been introduced in the mines for the detection of dangerous and poisonous gases.

Side by side the concept of Rescue of the persons involved in mine accidents also developed. No mine in the world can be made accident free no matter what gadgets and scientific instruments may be put to use. Wherever the mining work is carried out including drilling, blasting, mucking, transportation, un-loading, sorting etc., the accidents are apt to take place, may those be minor, major or fatal. There is not a single country in the world which can claim that their mining industry has not come across any accident. In the past many news have appeared in the papers and the magazines that major accidents took place involving therein lives of many workers. To deal with such catastrophic situations many



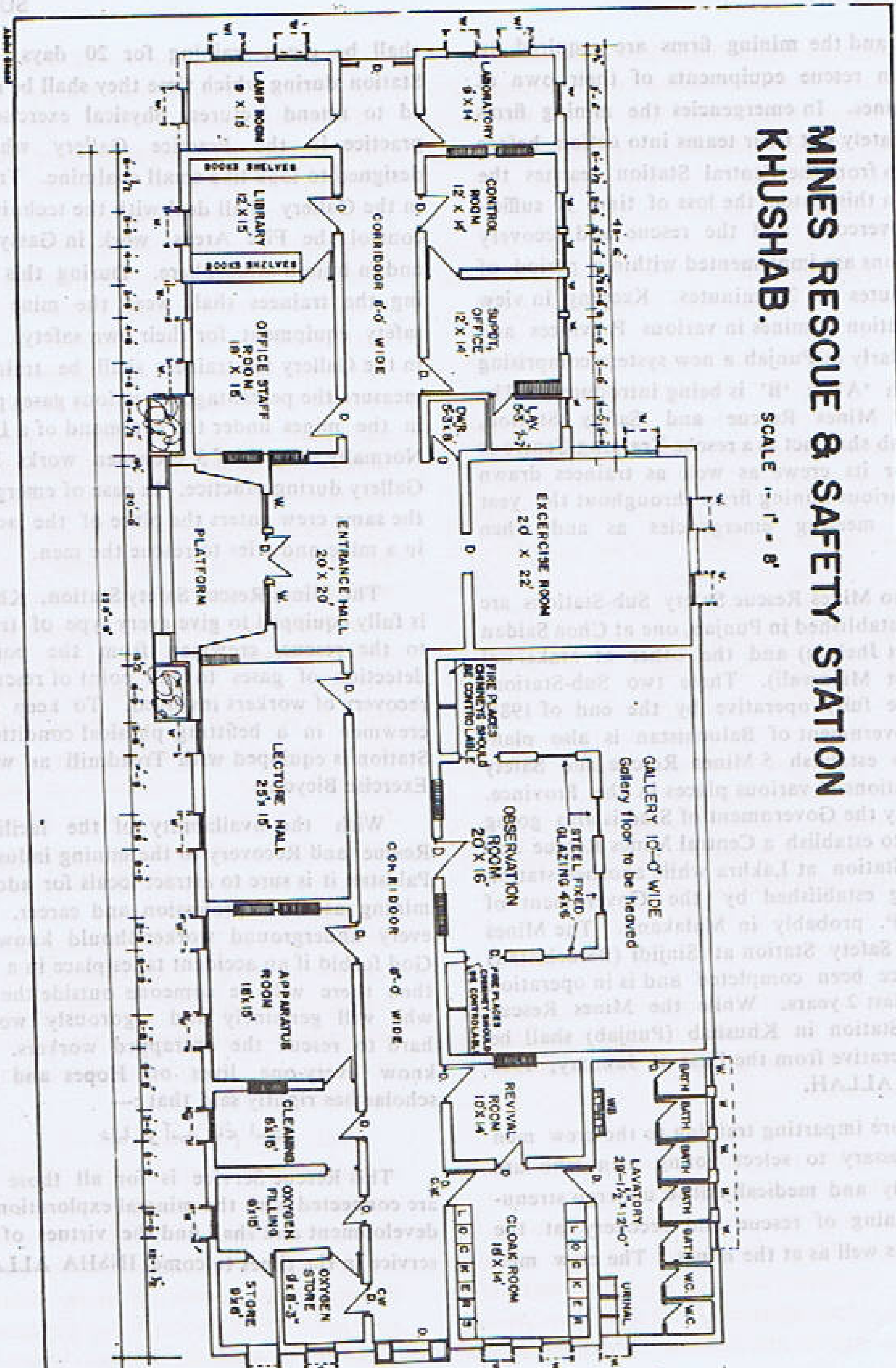
Photograph of Multi-Gas Director

countries have established Rescue Service in their countries. Leading among these countries are the United Kingdom, United States, Australia, Japan, India, Czechoslovakia, Poland, West Germany etc. etc. In this field of activity Pakistan has not lagged behind and has introduced a Rescue Service for the mineral operators, which is in fact the last hope for the persons who are involved in the mine accidents.

You and I while sitting over here may not be in a position to visualise or realise the gravity of the situation when one is involved into a mine accident. The mine accidents are no less grave than the accidents which take place in the air or in the sea. In all these three types of accidents i.e. in air, underground, and in the sea, the survival of the accidentees is not optimistic. Even then while travelling by air certain safety instructions are imparted to the passengers by the cabin crew. Similarly while travelling by ship certain safety instructions are imparted to meat the emergent situations. Likewise those persons who work in the gassy and dangerous mines are imparted safety instructions, besides equipping them with Self-Rescuers and other safety equipments for purposes of individual's safety. This is now a universal practice and being carried on by every mineral bearing country.

In Pakistan the safety and rescue facilities had totally been missing till late Seventies. It is heartening to bring to the notice of this august house that Rescue and Safety Service has been introduced very recently. In its initial stage two Mines Rescue and Safety Stations have been established. One at Sinjidi in Baluchistan and the other at Khushab in Punjab. These two stations have become now fully operative and are equipped with latest mine safety equipment. Both these Stations are located in the centres of mining activity and the rescue crews can be made to reach the site of the acident within an hour after the receipt of information at the Rescue Station. To facilitate the Central Station to receive information in the shortest possible time, different centres spurting with mining activity have been connected with the main Station by a net-work of Wireless System. If an accident takes place in a mine underground, it will take 5-10 minutes to reach this information to the surface provided the underground workings are not connected with internal net-work of telephone system. As soon as the information reaches on the surface office of the mine it shall be passed on to the nearest located Wireless Station, from where it will immediately be communicated to the Central Mines Rescue and Safety Station. On reaching the information at the Station the Sirons of the Central Station shall be put on and within a period of 5 minutes the Rescue Crew shall move to the site of the accident fully equipped with mine rescue and safety equipment. In other words Rescue Crew shall be on its move to the site of accident within 15 minutes of the time of the accident having taken place in the mine. The Crew would normally take 15 to 45 minutes to reach to the mine of the accident. During their travelling in the Mobile Van the Rescue Crew shall keep them busy in studying the underground maps. On reaching the mine of accident the Rescue Crew shall receive necessary instructions about the accident from the site management and proceed to the site of accident in the mine for the rescue and recovery of the accidentees.

This system is known as 'A' Şsytem and applicable in most of the mines in the Unietd Kingdom. This system is workable where the mines are concentrated but where the mines are scattered and located at far off places a Central Mines Rescue and Safety Station cannot render quick service. For far flung mining areas 'B' System is operated upon. In this system rescue teams of the mines are trained at the Central Mines Rescue and Safety


MINES RESCUE & SAFETY STATION
KHUSHAB.
SCALE - 1" = 8'
LAMP ROOM
BOOKS SHELVES
LIBRARY 12'X15'
CORRIDOR 8'-0" WIDE
OFFICE STAFF ROOM 18'X15'
ENTRANCE HALL 20'X20'
PLATFORM
LECTURE HALL
CORRIDOR 8'-0" WIDE
APPARATUS ROOM
CLEANING
OXYGEN FILLING
OXYGEN STORE
STORE
LABORATORY
CONTROL ROOM 12'X14'
SUPDT. OFFICE 12'X14'
EXCERCISE ROOM 20'X22'
GALLERY 10'-0" WIDE
Gallery floor to be heaved
STEEL FIXED GLAZING
OBSERVATION ROOM 20'X16'
REVIVAL ROOM
LAVATORY
CLOAK ROOM 16'X14'
URINAL
BATH
W.C.

Station and the mining firms are required to maintain rescue equipments of their own at their mines. In emergencies the mining firms immediately put their teams into action before the help from the Central Station reaches the site. In this system the loss of time is sufficiently overcome and the rescue and recovery operations are implemented within a period of 15 minutes to 20 minutes. Keeping in view the location of mines in various Provinces and particularly in Punjab a new system comprising of both 'A' & 'B' is being introduced. The Central Mines Rescue and Safety Station, Khushab shall act as a rescue Training Centre as well for its crews as well as trainees drawn from various mining firms throughout the year besides meeting emergencies as and when arisen.

Two Mines Rescue Safety Sub-Stations are being established in Punjab, one at Choa Saidan (District Jhelum) and the other at Makerwal (District Mianwali). These two Sub-Stations shall be fully operative by the end of 1984. The Government of Baluchistan is also planning to establish 5 Mines Rescue and Safety Sub-Stations at various places in the Province. Similarly the Government of Sind is also going ahead to establish a Central Mines Rescue and Safety Station at Lakhra while another station is being established by the Government of N.W.F.P. probably in Malakand. The Mines Rescue Safety Station at Sinjidi (Baluchistan) has since been completed and is in operation for the last 2 years. While the Mines Rescue Safety Station in Khushab (Punjab) shall be fully operative from the First of January, 1983 INSHA ALLAH.

Before imparting training to the crew men it is necessary to select young men who are physically and medically fit to undergo strenuous training of rescue and recovery at the station as well as at the mines. The crew men shall be given training for 20 days at the Station during which time they shall be required to attend lectures, physical exercise and practice in the Practice Gallery which is designed to look like small coalmine. Training in the Gallery shall deal with the technique to control the Fire Areas, work in Gassy Areas and in humid atmosphere. During this training the trainees shall wear the mine rescue safety equipment for their own safety. While in the Gallery the trainees shall be trained to measure the percentage of various gases present in the mines under the command of a Leader. Normally a batch of 5 crewmen works in the Gallery during practice. In case of emergencies the same crew enters the place of the accident in a mine and tries to rescue the men.

The Mines Rescue Safety Station, Khushab is fully equipped to give every type of training to the rescue crewmen from the point of detection of gases to the point of rescue and recovery of workers involved. To keep rescue crewmen in a befitting physical condition the Station is equipped with Treadmill as well as Exercise Bicycle.

With the availability of the facility of Rescue and Recovery to the mining industry in Pakistan it is sure to attract locals for adopting mining as their profession and career. Now every underground worker should know that God forbid if an accident takes place in a mine then there will be someone outside the mine who will genuinely and vigorously working hard to rescue the entrapped workers. You know every-one lives on Hopes and some scholar has rightly said that :—

دنیا بر اُمید قائم است

This Rescue Service is for all those who are connected with the mineral exploration and development and shall find the virtues of this service in the times to come, INSHA ALLAH.

GEOCHEMISTRY AT THE INSTITUTE OF GEOLOGY, PUNJAB UNIVERSITY, LAHORE

BY

SHAFEEQ AHMAD

Institute of Geology, Punjab University, Lahore

Abstract : *Geochemistry Section of the Institute started in 1963 as a small Chemical Laboratory to introduce students with methods of spot tests for minerals and for qualitative analyses. In 1965 by the addition of some latest equipments used for analysing rocks and minerals, the Institute, could produce three Ph. D. theses from the work carried out in this Laboratory. In mid-sixties Geochemistry was introduced as a subject in the M. Sc. curricula alongwith other related subjects like Soil Chemistry and Hydrocarbon Chemistry.*

This Section has produced hundreds of chemical analyses of different rocks to solve academic and research problems attached to study of granites, chromites, discovery of a number of minerals such as Tungsten, Molybdenum in Mansehra area, Cu, Ni, in Kaghan Valley serpentinites and Malakand Ultramafics. At present work is in hand on Geochemistry of Kirana Hills and Geochemistry of Speckled Sandstone Formation of Salt-Range. This Section has contributed not only to the Institute of Geology, and other departments of the Punjab University, Lahore but also provided technical expertise to a number of organisations such as NESPAK, PMDC, PUNJMIN and WAPDA. In the future development programmes, this Section plans to add more instruments.

HISTORY OF DEVELOPMENT

The Geochemistry Section of the Institute was started in 1963 as a small chemical laboratory to introduce to students methods of spot tests for minerals and for qualitative analyses. Such facilities were utilized by a number of students of the Institute of Chemistry during their M. Sc. thesis work. In 1965 when the Institute was shifted to the New Campus, the geochemistry laboratory was strengthened for major element analyses of minerals and rocks on the basis of classical methods. By 1967, such instruments were added, as spectrophotometer, flame photometer, colorimeter and differential thermal analysis. With this arrangement the Institute produced large number of first class analyses, and three Ph. D. Theses were produced, originating from the work carried out entirely in this laboratory.

Two posts of Research Officers were created to undertake regular geochemical work and side by side to provide help to other sections for testing geological materials and also to carry out joint research projects. The efficiency of this laboratory improved much with creations of these posts and addition of new equipment.

Initially, teaching of geochemistry was introduced only in mineralogy practicals for testing of minerals. In mid sixties, steps were taken to introduce geochemistry as a subject in the M. Sc. curricula. Courses were introduced for the M. Sc. Final year stage in geochemistry, soil chemistry and hydrocarbon chemistry, and in the current B. Sc. Third Professional class under the new scheme of B.Sc. Applied Geology four year degree course.

These courses have been prepared in line with the recommendations of University Grants Commission (1976). The Federal Ministry of Petroleum and Natural resources, while formulating development plans for the country had strongly recommended production of geochemist in the country with sufficient background of Geology and capacity to apply geochemistry in the professional field. In connection with technical man-power training in the Earth Sciences field, the need for geochemist was further highlighted. According to decision taken at the Federal level, this subject is to be developed at this Institute.

For the first time in the history of the Institute M.Sc. Thesis in this field started coming out in 1980-81.

RESEARCH CONTRIBUTION

In addition to M. Sc. and Ph. D. Thesis this section has produced hundreds of analyses relating to rocks of different nature to solve academic and research problems attached to them. Some of these includes origin of granite from different areas. Although geological work was carried out for the last about 17 years, yet this study lacked patrochemical data. In order to solve the granite controversy about its origin, chemical work was done to establish its genetic relationship with the metamorphics. This was a prominent step in the field of granite controversy.

The study of chromite was carried out to produce lot of new chemical data on such an important ore of Pakistan and to correlate its chemistry with its physical properties such as cell edge dimension, S.G. microhardness and refractive index. This latter study was made particularly due to the fact that chemical analyses of chromite is matter of some difficulty and time consuming. The above study, in addition to large number of chemical data, helped to derive a comparison of chemistry and physical properties of chromites, by means of which weight % of Cr_2O_3, Al_2O_3, Fe_2O_3, FeO, MgO can be determined within much shorter period. This can be of great help for metallurgists who require results within a short time. Another prominent feature of this study was that Harichand chromites are of refractory grade while Muslimbagh chromites can be used for metallurgical purposes.

This section has also played an important role in the discovery of a number of minerals. In Mansehra and Northern Areas, Prof. F. A. Shams (1956) was able to identify the occurrence of tungsten and molybdenum minerals in stream sediments which was traced back to the source area. Similarly Ni mineralization in Malakand ultramafics and Kaghan Valley serpentinites have been observed by the author. A preliminary geochemical work found presence of Cu and Ni in a number of rocks from Nomal-Chalt area in Hunza. This is the area of tectonic suture between Karakorum and Himalaya and represents remnants of an oceanic crust. Such areas in other parts of the world are known to be producers of important metals, so that present discovery is being made basis for a systematic investigation of this fault zone. The petrochemical and ore-microscopic study of Thak Valley igneous complex established its magmatic lineage relationship from tholeiitic parentage. This is the very first geochemical work carried out on Indus Ophiolite belt. Similar type of work is being extended to Shigar fault zone in Baltistan.

Keeping in view the petrotectonic importance related to the origin of glaucophane schists of Swat area, study of trace elements such as Cu, Ni, Co, Zn was carried out in order to establish their origin from basalts and/or from sediments.

Two major research projects are in hand. One research project relates to Geochemistry of Kirana Hills. These hills are projections of basement of the Punjab plains and are believed to be an extension of the Aravalli ranges. Analysis of some rock specimen showed the presence of traces of Gold, while iron ore is already being excavated. The need for a detailed work arose due to the nature of rocks, mode of origin and the peculiar association of metals.

The second project deals with the Geochemistry of "Speckled Sandstone" formation of Salt-Range. Salt-Range is a system of sedimentary formations and is considered geologically to be a sort of link between peninsular India and the High Himalayas. Salt-Range is believed to rest on the basement of oldest rock formation so that sediments were received by the weathering and transportation from Indian shield area in the south.

The Salt-Range has been famous for sedimentary mineral deposits such as Salt, Coal, Gypsum, Limestone, Dolomite, Silica sand, Clays etc. while no useful occurrence of metallic minerals is known with the exception of Cu and Mn. One Ph. D. student has been registered to work on this project.

The very usefulness and importance of this section is evident from its contribution. In addition to Ph. D. Thesis, so far more than 100 research papers have been published from this Institute on the basis of chemical work carried out in this section. These research papers have been published in local and foreign journals of International repute.

Apart from research problems related to academic nature, this section provided technical information to a number of organisations on their national projects. The departments include NESPAK., PMDC., PUNJMIN, State Cement Corporation, WAPDA.

FUTURE DEVELOPMENT PROGRAMME

In the future development scheme, it is planned to add more analytical instruments, such as Atomic Absorption Spectrophotometer. A detailed programme has been made to establish a geochemical technique for exploring the hidden deposits. In Pakistan there is great importance for geochemical work where Himalaya being a young mountain system has not suffered enough weathering and erosion to expose deeper level mineralization. A systematic geochemical survey will allow to identify area of interest which should then be followed by detailed geophysical and related investigations. Such a programme can also establish metallogenic provinces as a cheaper tool rather than applying expensive methods in areas of elementary information. The geochemical methods can also be extended to urban areas particularly near centres of industries so that any contamination of drinking water and soils by industrial wastes can be checked.

It is notable that out of all the geological methods, the geochemical methods have been given the least attention and require immediate consideration. One way of doing it is that geological parties of various agencies while doing their regular mapping in the field can also carry out geochemical tests simultaneously.

NEED FOR CO-OPERATION WITH INDIGENOUS INDUSTRIES AND TECHNOLOGIES FOR IMPROVING TEACHING AND SCIENTIFIC RESEARCH

BY

N. A. DURRANI

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Abstract : *There is no channel between the Universities and the Industrial Organizations for a bilateral exchange of scientific and technological data. In order to avoid the danger of being overwhelmed and over-dependent bv the technology of industrialized nations, intense development efforts had to be made to streamline the scientific education and research potential of the country. A constant research programme at Universities be carried out in co-operation with the Industry and research Organisations.*

Continuous flow of scientific and technological data is destined to play a very important role in the context of present and forseeable developmental needs of the third world, especially Pakistan.

It is sad, but undeniable fact that due to lack of communication channels between the Universities and the Industrial Organizations for a bilateral exchange of scientific and technological data, the maintenance of high academic standard in Pakistani Universities, substantial breakthrough in the scientific and technological field has almost become impossible. Under such circumstances the academic institutions in Pakistan have simply been reduced to the role of supplying manpower, rather stimulating scientific and technological research projects. The immense post-war development in the field of science and technology which has taken place in the developed countries—has created a dangerous situation for the existence and independance of developing countries. I apprehend, that unless intense developmental efforts are made by us in the field of science and technological research using indigenous manpower and resources, there is a danger of being overwhelmed and over dependent-by the massive influx of technology from the industrialized nations. To reduce the existing hiatus in the field of science and technological development in Pakistan new educational strategy would be required to streamline the scientific education and research potential of the country from the grassroot level to the higher academic institutes.

The basic interest while discussing this topic is to explore the possibility of a more reliable performance of higher educational system in Pakistan; and an evaluation of the present scientific education and research at the University level, its effectiveness and efficiency in meeting the Country's requirements and expectations from her national institutes. The Universities in Pakistan are going through a crisis period especially in relation to the initial objectives. In my view the factor which mostly influenced and impeded the quality of the Universities, can be traced back in few of thesevery potential aspects, such as funding, academic autonomy, planning, coordination, research and admission policy. Like many other developing countries to gain on the political front, the various governments in Pakistan too, from time to time allowed new institutions of higher education to be created even before the existing one which already were suffering due to limited financial resources and lack of administrative and academic infrastructure. Such short term political generosities had a diametrically opposite effect on the coantry's education system, and is also one of the reason which is responsible for the present chaos and destabilization seen around the various campuses in the country.

It is an important fact that the Universities are rare and most valuable asset of any nation and it is no exaggeration to say that the future of Pakistan in term of social and technological progress mostly depends on the extent to which its Universities can contribute the products of their scientific and technological research for the benefits of the peoples. To achieve this ultimate aim a more effective contribution from the government would be required for, the solution of the very real problems, mentioned earlier which are conforonting Universities in our country.

Although Pakistan now has specialists in most of the scientific and technological fields, but they are still far too few. Before the Pakistani Universities can fulfil their main objectives of performing research and dissaminating scientific knowledge, the acute shortage of staff, funding, laboratory and library facilities must be improved. Considering the financial constraints of the country, one possible solution is that various Universities should pool their available resources for sharing of certain facilities, and have joint research projects, whichdefinitely will help in consolidating the higher research programmes.

Funding has been a constant source of friction between the universities and the government, because the universities have difficulties hoth in securing adequate financial support for their minimum needs and in attracting and retaining qualified staff.

In light of the above mentioned difficulties, it is becomming increasingly hard for the faculties in any University to continuously maintain the academic excellence, while fighting for their survival. Like many other developing countries, in Pakistan too, their is lack of academic independence and the decision making at the departmental and faculty level by the professionals are subjected to administrative vetos and manipulations. The effect on the scientists of these tribulation is mostly bad. Moral is low, and initiative is falling away. The point has reached now where the research and teaching department at the univesrities are completely isolated and their primary objectives have been severly reduced.

The present system of enrolment at the university level brings a yearly influx, despite the limited opportunities. Selective admission policy would be more suitable, as this would help in adopting a compromise between social demands and manpower needs. Because of the present pressure tactics used at the time of enrolments, it is often that those who are below average manage to enter the universities resulting in a further decline of the teaching standards. I am positive that most of you understand and agree with me about the implications and the cost we are paying for the disregard for an automatic right of entry for qualified entrants. I suggest that the need for a system of selection at the point of entry has to be seriously implemented. There is, therefore, an obvious continuing need for a well-oriented policy in this regard and which should form a basis for the contemporary needs of the country in the field for scientific and technological programmes. Present curricula is often questioned, because it is often that it has no relevance to the needs of industry and research organisations. It is, therefore, necessary that a constant reassessment of teaching programme be carried out in co-operation with the industry and the research organisation. This interchange of ideas should also help the present lack of communication between the Universities and the industry, this way we should be able to tailor the teaching curricula to the requirements of national development.

PROSPECTS OF OIL/GAS WITH THE DIAPIRIC SALT IN THE SALT-RANGE

BY

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Abstract : *The various oil producing horizons of the Potwar region make favourable structures for oil with diapiric salt in the Salt-Range.*

As per present knowledge, the eastern flank of the Chisel Algad Valley and the adjoining Mari Indus near Kalabagh, afford bright prospects of oil at relatively shallow depths.

Results of the recent detailed investigation for salt in different parts of the Salt-Range by PMDC strongly suggest a deviation from the old aproach of searching oil at the anticlinal folds, to the flanks of the intrusive salt bodies specially where they cut through vertically or at steep angles.

The presence of oil seepages at or near major disturbance zones in the Salgi valley near Amb/Warcha and at Chhidru further indicates the existence of favourable conditions and brightens prospects of tapping oil in other 'intact' blocks.

Prospects of oil/gas in the Salt-Range originate from the hypothesis that this range is not a normal mountain range rather it is the remnant of a large, ruptured and 'discharged' salt dome.

This hypothesis has emerged as an outcome of the recent geological investigations conducted by the author in his capacity as Incharge exploratory operations of the Pakistan Mineral Development Corporation in the Salt-Range and Kohat. The said work on the basis of which new inferences have been drawn includes detailed topogeological mapping and thousands of feet of core drilling in the Eastern, Western and Central Salt-Range.

The key role in the development of the new picture of the Salt-Range has been played by the mode of occurrence of the Pre-Cambrian salt (known as the Saline Series or the Salt-Range Formation) which constitutes the bulk mass of the Salt-Range and on which floats the relatively thin and frequently punctured (with salt) mantle of Cambrian-Pleistocene strata.

The subject of the nature and age of the Salt-Range salt or the Saline Series (Salt-Range Formation) has been controvercial in the past within the geologic circles of the Indo-Pak subcontinent. Regarding the age and contact relations of the Saline Series, D. N. Wadia comments at pages 141-142 of his 'Geology of India' (1957) :—

"The age of the lowest group, composed of salt-marl, gypseous marl, salt, gypsum and dolomite, presents a difficult problem which has long been one of the major controversies of Indian geology. The boundary between the Saline series and the overlying Purple sandstone is much disturbed and is undoutedly not a regular one. This fact has been interpreted in different ways; one view is that this disturbed boundry is merely the result of differential movement between two very different types of rock-the very "competent" Purple sandstones, and the soft, plastic, and "incompetent" beds of the Saline series; another interpretation stresses the effects of solution of saline material and suggests that this has led to the severe disturbance and brecciation noticeable wherever the Saline series is in contact with other rocks. A widely different interpretation has been put forward by several geologists and is supported by recent work. It is that the apparently infra-Cambrian position of the Saline series is due to a large overthrust and that the salt-marl and associated beds are really of Eocene age. B. Sahni has found micro-fossils of angiosperm plants embedded in the salt, gypsum and associated rocks from different outcrops of the Saline series. About the indigenous nature of these micro-fossils, however, some doubt has been expressed".

Presently the Salt-Range salt is considered, as an 'established' fact, to occur in situ as lenses and lenticular beds in a normal sedimentary formation known as the Salt-Range Formation of Pre-Cambrian age which consists mainly of marls, salt-marls and gypsum and which attains a huge but unknown thickness (at least in the type section) as its base has not yet been touched even by a bore hole as deep as 8,518 feet (2,597 m) drilled at the axis of a broad anticline of the Salt-Range 'anticlinorium'.

But the outcome of the above referred recent geological work of the author is somewhat different and contrary to the presently accepted and 'established' position. In brief, the author has been led to the conclusion that throughout the Salt-Range and in Kohat area the salt is not in situ and does not occur as a normal member of the straigraphic sequence, rather it is diapiric and constitutes typical diapiric structures e.g. salt domes or 'stocks', 'salt walls' (as defined by F. Trusheim, 1960) and 'salt flows'. In other words, it is understood that the Salt-Range is not a normal mountain range rather it is the remnant of a huge and complex salt dome and the main salt belts of Kohat are not normal anticlines with salt in the core rather they are typical salt walls and/or remnants thereof.

The author maintains that the presently accepted division of the so-called Salt-Range Formation is whimscial and arbitrary as it has not been found valid in its actual sense for any part of the Salt-Range, not even for Khewra which is supposed to be the type section. The so-called Brignt Red Marl, Dull Red Marl and the Bhandar Kas Gypsum etc. are considered to be nothing but the bluish grey (weathering to red) marly anhydrite 'cap rock' (encl. 15) of the salt diapir; or the brownish red uncompacted residual soil or rubbly clay of the salt which occurs as a surficial mantle of variable thickness over the exposed salt masses; or the rootless and irregularly placed lenticular bodies of anhydrite, marl and dolomite etc. occurring within the salt mass from place to place. The last item represents the distorted and dislocated evaporite beds which occurred interbedded with salt in the original 'Saline Series'. The various analysis reports contained in the following tables shall afford some confirmation to this statement :—

TABLE 1

Analysis reports* of fresh and oxidised cap rocks (Bright Red Marl) at Warcha and Khewra

	Fresh/unoxidised (Bluish grey) Warcha		Oxidised (Red) Warcha		Oxidised (Red) Khewra
Sample No.	201 (27-B)	385	201 (27-A)	386	470 (1)
Fe	0.6	0.5	1.3	1.4	1.4
SiO_2	35.6	30.1	4.9	30.0	22.2
Al_2O_3	6.2	5.8	5.7	5.8	3.4
CaO	16.2	23.8	22.6	22.2	8.3
MgO	8.5	9.4	11.6	11.7	10.1
SO_4	12.0	17.9	17.2	13.4	31.1
Ign. Loss	17.3	Not determined	16.2	Not determined	12.5

*Samples analysed by Ishtiaq Hussain Dy. Chief Chemist, PMDC Central Mineral Testing Labs. Rawalpindi.

TABLE 2

Analysis reports* of the residual soil of salt (Dull Red Marl) at Khewra

	Residual soil or 'Dull Red Marl' collected from the outcrop, western wall Khewra gorge	Residual soil produced by the salt leaching plants of ICI's Soda ash Works, Khewra
Sample No.	472 (3)	471 (2)
NaCl	12.5	17.0
Fe	1.7	1.2
SiO_2	26.0	20.8
Al_2O_3	4.9	3.0
CaO	1.0	—
MgO	12.6	13.7
$CaSO_4$	26.9	33.0
K_2O	0.2	0.2
Ign Loss	12.8	10.7

*Samples collected by Muzaffar Hussain Assistant Geologist and analysed by Ishtiaq Hussain Dy. Chief Chemist, PMDC Central Mineral Testing Labs. Rawalpindi.

TABLE 3

Analysis reports* of the so-called Bhandar Kas Gypsum horizon, Khewra (Channel Sample No. 473 (4) collected from Bhandar Kas Nullah)

Fe	10.5
SiO_2	6.3
Al_2O_3	1.0
CaO	10.1
MgO	9.1
$CaSO_4$	58.0
K_2O	0.1
Ign. Loss	14.3

*Sample collected by Muzaffar Hussain, Assistant Geologist and analysed by Ishtiaq Hussain, Dy. Chief Chemist, PMDC, Central Mineral Testing Labs. Rawalpindi.

Regarding the Salt-Range similar views are understood to have been held by 'Jean W. Schroeder' by way of its comparison with the Persian gulf salt domes in his article titled "Geologie de l ile de Larak contribution a l'etude des domes de sel du golfe Persique comparison avec la Salt-Range" as early as 1946.

Also, in his recent geological maps of the Salt-Range titled 'Salt-Range Series (1980), E. R. Gee who happens to be the ex-Director-General, Geological Survey of Pakistan (GSP), has shown atleast some of the salt areas to consist of diapiric salt instead of normal-bedded or in situ salt. He has also shown in his maps, salt extrusions through some of the faults. In his private communication of 1-12-1981 addressed to the author he comments :

"As regards '1' (part played by Diapirism), you apparently consider that diapirism has played a major role in the definition of these deposits as exposed today, and there is no doubt that this is so, particularly in the case of the Kohat area and around the Kalabagh-Mari Indus reentrant ; also at several other places along lines of acute faulting in the Salt-Range.

In the case of *main* anticlines of the Salt-Range, however, it is remarkable that there are few instances of the salt intruding upwards the overlying Middle Cambrian and younger sequence as 'plugs' or 'stocks'. For some years I have regarded these main anticlines to be the result of uplift pressures due in part to late Tertiary-Pleistocene tectonism (the forefront of Himalayan orogeny) and in large part to the flowage of salt southwards from the Soan geosyncline, under the weight of the immense thickness of Murree and Siwalik sediments deposited there as compared with a much thinner sequence in the Salt-Range area. This movement of the salt southwards led to its duplication in the main Salt-Range anticlines, as indicated by the great thickness of the Salt-Range Formation (2,100 metres plus) in Attock's Dhariala bore hole.

In other words, I regard the main domes of the Salt-Range anticlinorium as underlain by 'salt-pillows' as defined by F. Trusheim (see 'Mechanism of salt migration in northern Germany' in A.A.P.G. Bull. Vol. 44, No. 9 September, 1960 pp. 1519-1540)".

Finally, the views on the diapiric or domal nature of the Salt-Range are summarised to the following points :—

1. When subjected to such severe tectonic conditions as prevailing throughout the Salt-Range, it is natural for such thick masses of salt and related evaporities as encountered in the Salt-Range Formation, to become diapiric.

2. The various bore holes drilled so far in the Salt-Range Formation in various parts of the Sall-Range, have all entered in massive and never ending salt after a 50 to 200 feet (15 to 61 m) zone of either loose rubbly soil or of impure anhydrite/gypsum, and marl etc. None of the bore holes has been able to verify the presently accepted lithological units of the Salt-Range Formation.

The same is true of the various salt mines and quarries which are scattered, like the bore holes, in the western, central and eastern Salt-Range. The bore holes and mines have exposed sections of salt upto depths of about 500 to 8,500 feet (152 to 2,591 m) from the surface.

3. The general trend of salt as noted in various bore holes and salt mines in the Salt-Range, is not conformable with the overlying younger formations and with the general structure of concerned areas. In most cases there is a sharp and unmistakable contrast. For example in the famous 8,518 feet (2,597 m) deep bore hole of the Attock Oil Company at Dhariala (Eastern Salt-Range), the dip of the overlying strata from Eocene to Cambrian and of the cap rock (the anhydrite-gypsum zone at the top of salt) which in total constitute a depth or thickness of 1,562 feet, varies from 0° to 4°. But the dip of salt which continuous from 1562 feet to 8,518 feet, ranges from about 25° to 70° (actual range is 10° to 80°) with dips around 70° being more common, (see encl. No. 6).

4. Irrespective of its position in any part of the so-called Salt-Range anticlinorium, the salt has been found to maintain northerly dips, and the internal flowage structures wherever noted are invariably bent to the south, all pointing out to salt flow from north to south in general.

5. Flowage structures resembling to the typical flowage structure of gneisses are commonly seen in the salt from place to place throughout the Salt-Range. Special localities are Kalabagh, Mari Indus, Warcha and Khewra (see encls. Nos. 12, 13 and 14).

6. At some places in the Salt-Range, flat and gently inclined salt beds have been resting over the denuded edges of the younger formations. Apparently, these are clear evidence of salt-flows on the one hand and of the fact that salt movement has been active until recently, on the other.

Jutana area (Eastern Salt-Range) and Golewali area (Central/Western Salt-Range) are good examples of this phenomenon. (see encls. Nos. 8 & 9 and photo slides Nos. 1 to 6).

7. Extrusion of salt along certain major fault planes in Siwalik areas in the Salt-Range are clear cut examples of diapirism. Ainwan and Mari Indus salt areas in the western Salt-Range and Vasnal salt area in the Central Salt-Range are good examples. (see encl. No. 3).

8. In the main tunnel of PMDC's Warcha Salt Mine (Central Salt-Range) the gently dipping salt has a direct contact with the recent Warcha nullah (ravine) debris consisting mainly of water worn pebbles and boulders of Limestone (Permian). The tunnel has been driven in this loose debris for a length of 1,002 feet (305 m) to hit the first salt Close to the contact with salt, the loose debris has been compacted and brecciated. Moreover, further up the contact undigested limestone debris layers, patches and irregular shaped bodies may be seen entombed in the salt from place to place for a length of about 450 feet

(137 m) in the tunnel (see encls. Nos. 4 & 5 and photo slides 7, 8, 9 and 10).

Further, above the Warcha salt mine the salt occurs in direct contact with Sardhai, Wargal or Chhidru Formations (Permian) all of which are shattered and in a bad shape. The intervening incompetent sandstones and shales of Khewra Formation (Cambrian), Dandot Formation (Permian) and Warcha Formation (Permian), which together constitute a thickness of about 600 ft. (183 m) in this area, are all missing. All of these formations which are exposed in normal sequence in the adjacent Warcha and Jan Sukh gorges, have apparently been squeezed out, between the rising salt diapir and the rigid block of the massive Wargal Limestone.

Similar conditions prevail at places in the adjoining Kaurhian Valley, Dhoda Wahan Valley and Golewali Valley etc.

9. In the Kalabagh area a huge salt mass (part of a diapir) has lifted up overhead as its 'crown' a completely isolated and rootless hotchpotch mass of intricately folded rocks from Permian to Pleistocene in age (see encl. 2). The most prominent formation in this jumble is a boulder conglomerate consisting of boulders of various formations above the salt from Permian to Eocene.

It must however be accepted that the Salt-Range diapir is unique and in parts deceptive in its kind, that's why it has not yet been identified and accepted as a diapir. An important factor which is considered to have contributed much to its deceptive nature is probably the outburst and subsequent erosion at most of the localities of the main body of the original frog-shaped diapir leaving behind part of its 'back' only. Accordingly what was the main body of the massive diapir and its salt glacier, is now the flat plains of brown soil south of the Salt-Range proper.

There are instances to indicate that uparching by salt in the Salt-Range was not uniform throughout. At places it had reached rupture stage while at others it was still in the 'salt-pillow' stage. There are also indications to believe that the Salt-Range had started rising in the Eocene epoch during the deposition of the Sakesar Limestone. This follows that normal deposition of the Eocene (upper) and specially the post-Eocene strata as found in the Soan geosyncline and in the Mianwali-Sargodha area, has not taken place in all parts of the Salt-Range proper. A good example is afforded by the Salgi oil seepage area in between Warcha and Sakesar. (see encl. No. 10). Here an axial block with the originally deposited Sakesar Limestone and the overlying rocks has been preserved by trough faulting within Permain strata. In this block, the Sakesar and Nammal Formations which together normally range in thickness from 300 feet to 400 feet (91 to 122 m) in this part of the Salt-Range, are only about 75 feet (23 m). And out of this too only the lower about 35 feet (11 m) consist of normal Sakesar Limestone while the upper half consists of a limestone boulder-conglomerate of the same limestone. Moreover, the conglomerate makes an angle of 10° to 15° with the underlying limestone i.e. it is unconformable. This limestone conglomerate, which is considered to be a part of Sakesar Formation is followed mainly by a zone of Siwalik type loose greenish grey sandstones and red weathered blue-grey shales with oil seepages chiefly ensuing from shale-sandstone contacts from place to place. At the top of this approximately 200 feet (61 m) sandstone-shale zone, is a lenticular (being in drag) zone of typical Kalabagh type conglomerate i. e. consisting of pebbles and boulders of older formations of the same area.

The author has tried to explain the mechanism of diapirism in the Salt-Range, as understood by him, by the three sketch geologic sections appearing under enclosure No. 11.

Occurrence of the 'salt glacier stage' in between the diapir stage and the current or 'settled' stage has been indicated by :—

1. The general 'rush' of salt to the south irrespective of the behaviour of overlying strata as observed in the underground workings of various salt mines throughout the Salt-Range.
2. The general southwardly trend of the flowage structures in the salt throughout the Salt-Range wherever developed/seen.
3. The constitution of the southern plains.
4. The various remnants of 'salt flows' at different places in the Salt-Range e.g. Jutana and Golewali etc.

To qualify at least the (3) above expression may be given to the fact that the surface soil of most parts of the extensive plains south of the Salt-Range consists upto the exposed depths, of a brown, light weight, rather spongy clay which is devoid of any observable bedding. This clay at most of the places, is also devoid of the heterogeneous water worn pebbles/boulders and of loose sand beds, typical of the river deposited material. It resembles very much to the residual clay of the salt outcrops minus of course the observable gypsum fragments which may have been decomposed under more favourable conditions at the plains.

The conditions indicate that the Jhelum river marks the boundary of the old salt-glaciers from Jhelum city upto its main bend at Khushab and from there upto Mianwali, the Khushab-Mianwali road roughly constitutes the boundary of the said salt-glaciers which are considered to have ensued some time in the post-Siwalik period from the 'bursted' diapir of the Salt-Range.

Presence of salt in the southern plains at relatively shallow depths below the mantle of the brown residual clay is also indicated by the existence of brine springs, brine pools and saline marshy areas from place to place specially in the Khushab-Katha area, Central Salt-Range.

After it is established that our famous Salt-Range is actually a salt-dome, it would probably be simpler to assess its importance as much bigger and more essily and cheaply worked reserve of high quality salt and probably also a similar source of oil/gas specially in view of the fact that the various oil bearing formations of the so far chief oil fields of Pakistan i.e. Potwar area, make very promising structures from place to place against the walls of salt and related evaporites which are known as the most effective oil seals of the nature.

As is known to us from the geology of the salt/oil fields of the gulf states of U. S. A., Mexico and of W. Germany etc., oil is mainly searched for, in areas with favourable sedimentary strata and salt dome activity, at the periphery of intrusive salt bodies. The selection of drill hole sites is quite tricky in such cases as in plan, there is generally a narrow belt of oil/gas bodies at the periphery of the salt dome. A slight mis-assessment may put the entire hole in salt or in the barren parts of the oil bearing strata. The problem may be eased if the prospecting agency is financially sound and can afford rather liberal drilling. The Germans have drilled over 13,500 wells for oil/gas (as against the total of less than 150 wells in the entire Pakistan) in their salt domes region to have at least 3,300 production wells.

In the case of the Salt-Range dome however, the problem is a bit different. Due to the special shape and 'case history' of this huge elongated dome, quite a bit of the strip at its northern side made probably be safely disregarded. Apparently the southern plains, from Kuch village near Kalabagh in the west upto Jhelum city in the east should bear the oil/gas belt parallel to but at some distance from the southern foot hills of the Salt-Range. As a rough assessment, the oil/gas belt in question should not be located beyond the Jhelum River in the Jhelum-Khushab area and beyond the Khushab-Mianwali road in the Khushab-Mianwali area. It is estimated that the Kundian test hole (which went dry) was located too much to the south. To establish the oil belt the southern boundary of the Salt-Range dome is to be established by seismic methods followed by relatively short confirmatory holes in the southern plains.

Along the western boundary of the Salt-Range Dome nature has afforded us an apparently very promising area as the Chisel Algad Valley located north of Kalabagh. In this valley clear cut exposures may be observed from place to place where the uparched Siwalik strata is terminated against a more or less verticle wall of salt for a distance of about seventeen kilometeres. The various main oil bearing horizons of the Potwar are expected to underlie the Siwaliks under similar and highly favourable conditions (encls. Nos. 2 and 13). Further, the area east of the Chisel Algadvalley has clear exposures, without any vegetation or debris cover, which indicate fairly undisturbed conditions.

In view of the foregoing, it would not be improper to conclude that the Salt-Range, or the "Kalabagh-Jhelum salt dome" as it may better be called, shows quite good prospects of bearing workable deposits of oil/gas. To tap these deposits however it is imperative to switch over from the present over-adhered 'anticline-oriented approach' of oil exploration to 'salt dome-oriented' one.

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LIST OF ENCLOSURES

Title

1 Location map of the Salt-Range showing salt exposures and approximate positions of the projected oil/gas belts.

2 Location map and geological section accoss the Salt-Range through the Kalabagh hill showing position of the proposed bore hole for oil/gas.

3 Geological section across the Mari Indus limestone hill showing the position of salt deposits and Bore hole Nos. 1, 2, 4 and 8.

4 Geological section across the Warcha salt mine.

5 Section of rocks as exposed at the eastern wall of Warcha salt mine's main tunnel.

6 Geological section across the Salt-Range through Dhariala, Dalwal and Makrach areas showing the position of proposed/drilled bore holes.

7 Geological section across the Salt-Range from Khewra at Katas.

8 Section of rocks as exposed at the South-eastern wall of Kas Kaurha nala near Jutana showing the recent flow of salt over the denuded surface of younger Khewra Formation.

9 Geological section across the Golewali salt exposure showing the flow of salt and associated evaporites over younger rocks and the curved edges of Warcha Formation underneath.

10 Geological section across the Salgi Valley showing the position of Salgi Oil seepage zone near Warcha.

11 Generalised geologic sections showing the suggested mechanism of salt migration in the Salt-Range.

12 Photograph showing an injected pipe of salt (Pre-Cambrian) in the Siwalik shales (Miocene-Pleistocene) at Mari Indus Western Salt-Range.

13 Photographs showing the Salt-Siawalik contact and the flowage structures in salt at the Chisel Algad Valley near Kalabagh Western Salt-Range. Distant and closer views.

14 Photograph showing flowage structures at a salt cliff at Mari Indus, Western Salt-Range.

15 Photographs showing the alteration of the bluish grey marly anhydrite of the 'cap rock' into the so-called 'Bright Red Marl' in the Warcha valley, Central Salt-Range.

PHOTO SLIDES

Description

1 Salt flow over the denuded surface of Khewra Formation near Jutana, Eastern Salt-Range. Distant view.

2 Salt flow over the denuded surface of Khewra Formation near Jutana, Eastren Salt-Range. Closer view of the Central and northeastern part.

3 Salt flow over the denuded surface of Khewra Formation near Jutana, Eastern Salt-Range. Closer view of the south-western part.

4 Salt flow over the denuded surface of Khewra Formation near Jutana, Eastern Salt-Range. Closer view of the central part.

5 Flow of salt and related evaporites over the denuded surfaces of the younger Warcha and Dandot Formations in Golewali area, Central Salt-Range. Distant view.

6 Flow of salt and associated evaporites over the denuded surfaces of the younger Warcha and Dandot Formations in Golewali area, Central Salt-Range. Closer view.

7 The unassorted boulders and pebbles as seen in a manhole in the main tunnel Warcha Salt Mines, Central Salt-Range, at a distance of about 800 feet from the tunnel mouth.

8 An undigested melon shaped body of crushed limestone pebbles in salt, Warcha Salt Mine, Central Salt-Range.

9 Contact of the brecciated and partly altered Wargal Limestone debris and salt in the Warcha Salt Mine, Central Salt-Range.

10 Contact of the brecciated, partly altered and saliferous Wargal Limestone debris and salt in the Warcha Salt Mine, Central Salt-Range.

11 Contact of one of the so-called potash beds with normal salt in 22nd Chamber Khewra Salt Mine, Eastern Salt-Range.

12. Network of the white salt 'dykes' in the normal pink salt in the Khewra Salt Mine, Eastern Salt-Range.

Note :—Readers interested in the diagrams may contact the author.

EXPLORAITON AND EVALUATION OF DHARIALA POTASH BRINE, SALT RANGE, PUNJAB

BY

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Abstract : *The occurrence of brine deposit containing 6.7% potash and compounds of other useful minerals like magnasium, boron, etc. was discovered by Attock Oil Company while drilling for oil at Dhariala near Choa Saiden Shah in District Jhelum in 1952 at three horiozns at depths of about 3,939 ft. 4,424 ft. and 8,518 ft. The most promising horizen was the one at 3,939 ft. from where brine flow to the surface at a rate of 1,500 barrels per hour with a pressure of 720 psi. Samples of brine were collected and analysed by several chemical laboratories in Pakistan and England. An average composite of the laboratory analysis showed that the brine contained by weight, 6.7% potassium chloride, 16.5% magnesium chloride, 4.6% calcium chloride, 5.7% sodium chloride and small quantities of sulphate derivatives.*

Potash being an important fertilizer mineral; former WPIDC took up further evaluation of the deposit in 1968 and made two abortive attempts to drill down to the brine horizon with the help of Romanian drilling equipment and experts. The failure lad WPIDC to close down the project in 1969.

Keeping in view the importance of potash for agriculture and industry, Punjmin took up the project in 1976 under an approved PC-II scheme. Phase-I of the scheme comprising geological hydrological and geophysical surveys was completed by Punjmin in June, 1979. On the basis of this work, Punjmin was able to select four sites for drilling down to an average depth of 4,500 ft. followed by flow tests in order to properly evaluate the deposits for quality and quantity.

In phase-II programme of drilling of four holes alongwith and the associated work referred to above will be undertaken subject to approval of Government.

INTRODUCTION

Presence of potash in the saline series of Salt-Range has been reported by eminent geologists. Christie (1914) described the locations of potassium salts in the Khewra mine and also at Nurpur. Sturat (1919) detected the presence of potassium salts in the salt mines at Warcha and Kalabagh. Economic potash deposits are mainly found in association with evaporite minerals like gypsum and halite.

Till early fifties of the twentieth century, Attock Oil Company (AOC) was the main operating agency for oil exploration in Potwar Plateau. They carried out extensive geological investigation within Potwar Plateau and adjoining areas to locate structures favourable for oil accumulation. They also explored the Cis-Indus part of the Salt-Range for the purpose and discovered an east-west striking anticlinal structure of appreciable dimensions about 4 km north-west of Choa Saiden Shah, later named as Dhariala-Khajula Fold. On selecting a site for drilling on the top of the anticline, one mile west of Khajula village, AOC started drilling operations in 1951.

AOC drilled up to a depth of 8,518 feet, but could not be successful in the objective of finding oil. Instead, they encountered a heavy flow of brine under artesian pressure at a depth of 3,939 feet. The brine had a flow of 1500 B/hr with closed-in pressure of 720 p. s. i. They also encountered brine horizons at depth of 4,418 feet and 8,003 feet but with much less flow. AOC then decided to abandon drilling and reported the discovery of brine to the Government. At the same time, the brine samples were analysed in Pakistan and Great Britain. An average composition of chemical analyses showed that the brine contained, by weight, 6.7 percent potassium chloride, 16.5 percent magnesium chloride, 4.6 percent calcium chloride, 5.7 percent sodium chloride, small quantities of sulphate derivatives and traces of other elements.

In 1968, Pakistan Government assigned the exploration and evaluation of the brine to West Pakistan Industrial Development Corporation (WPIDC) who made two attempts to drill at the same place using a Romanian drilling rig with the assistance of experts of Geomin of Romania and also Oil and Gas Development Corporation but failed to reach the brine horizon because of some drilling and mechanical problems.

In 1975, Punjab Government created Punjab Mineral Development Corporation (PUNJMIN) to explore and develop potential economic mineral deposits in the province of Punjab. PUNJMIN prepared a project in the name of "Exploration and Development of Dhariala Potash Brine" and undertook the responsibility of exploration and evaluation of potash brine reserves in the Dhariala-Khajula Fold. This project is of great importance and magnitude in a way that never before such deep drilling has been required for a mineral project in Pakistan other than oil and gas.

GEOLOGY OF THE AREA

The area under investigation lies in the Cis-Indus part of Salt-Range and is limited by latitudes 32° 43′N to 30° 46′ 35″N and longitudes 72° 53′E to 72° 59′ 30″E. The area surveyed on scale 1:10,000 is approximately nineteen sq. miles.

The surface area is characterized by long, narrow, sub-parallel folds and faults. Trend of these folds and faults indicates a conjugate-shear system which is the result of regional north-south compressional forces.

Dhariala-Khajula fold is represented by an asymmetric anticline with its axis running in an east-west direction and showing plunges on its eastern side. The general dip of strata is north-west varying from 10° to 40°. The general structure of the area resembles close set anticlines and synclines which are more or less fractured by overthrusts. Dhariala-Khajula fold is situated near the frontal zone of a regional belt to the north of the area.

The area is studded with nallahs which are generally non-perennial and flow in a north-south direction. The discharge of such nallahs show trellis pattern and display a system of sub-parallel streams aligned along the strike of rock formations.

Rocks exposed in the surveyed area are of Tertiary age, and comprise finely bedded, thick massive limestone and sandstone which show conformable contact with each other. Presence of older rock units is confirmed from data of Attock Oil Company's borehole drilled upto a depth of 8,518 feet.

The structural model computed by Punjmin in collaboration with Williams Brothers Engineering Company of U. S. A. (WBEC) shows that the area is positioned along the marginal line separating Salt-Range and Potwar Plateau and occupies the central main basin which lies in between 72° 55′ and 72° 57′E.

OBJECTIVES

Briefly, the objectives of the PUNJMIN project was as follows :—

Phase-I. (i) Carry out geological and geophysical surveys to locate favourable structure for discovery of brine reserves

Phase-II. (i) To drill appropriate number of holes to prove the extent of brine reserves, and

(ii) carry out flow and associated tests to determine the size of the reserves and quality of brine.

METHODOLOGY

AOC drilled the well mentioned above over Dhariala-Khajula Fold on the basis of geological information alone. They never carried out any geophysical work to see the behaviour of the geological sequence in the sub-surface. WPIDC also drilled near the same site mostly depending upon the AOC well information. Punjmin, being little more careful before spending a huge amount on drilling, decided to carry out gravity and magnetic survey over the Dhariala-Khajula Fold, to study the structure and also check the extent of saline reserves which may be present in the core of the anticline so that exact locations of the drilling sites may be decided.

First of all, gravity and magnetic surveys were carried out simultaneously in collaboration with Department of Earth Science of Quaid-e-Azam University, Islamabad to cover an extensive part of Salt-Range for evaporite minerals which also included Dhariala-Khajula Fold. A Worden Gravimeter and two Proton Magnetometers were used to carry out the surveys. Stations were placed at ½ mile interval and spacing between two profiles was three to four miles. Heights of the stations were measured with two Paulin Altimeters.

In the beginning of 1978, a contract was awarded to WBEC to make a preliminary study for commercial development of Salt Range brine minerals, mainly emphasizing Dhariala-Khajula Fold. As use of satellite imagery is a more versatile and efficient method and provides a clear understanding of structure and stratigraphy of the area, WBEC studies were mainly based on satellite imagery of the area. It involved utilisation of imagery in conjuction with aerial photographs and previous geological work. Although, the study was of preliminary nature, sufficient geological knowledge was obtained to construct depositional and structural models of the Salt-Range. This is the first time that satellite imagery was used for a mineral project in Pakistan.

Two experts of Geomin of Romania also visited the area and recommended three sites for exploratory drilling in the vicinity of Dhariala-Khajula Fold and also to study the hydrological sites of the area.

Geological mapping was carried out on a scale 1:10,000 and it confirmed the structure. The area covered on this scale was approximately 19 sq. miles. Water samples from natural springs and seepages in the area were also collected in order to determine their chemical constituents.

GEOPHYSICAL WORK

As a result of gravity survey, a negative anomaly of appreciable amplitude emerged on different gravity maps which roughly corresponded with Dhariala-Khajula Fold. The extent of anomaly measured on Bouguer map came to be 13 × 8 sq. miles with an amplitude of 10 mgals. The area where Dhariala anomaly is located, is considered deepest portion of the main depositional basin marked in the portion between Basharat and Vasnal, where maximum thickness of Salt-Range Formation may be expected.

CONCLUSION

Pakistan is a developing country. Agriculture is the mainstay of its economy. At present, need for potash fertilizer is the basic requirement of the country to overcome the food shortage and be self-sufficient in the near future.

Under such conditions, the discovery of brine containing an appreciable percentage of potash can play an important role in stablizing the economic position of the country by saving crores of rupees in foreign exchange being spent on the import of potash fertilizers. It is interesting that the chamical analysis of brine encountered in the AOC well-indicated the presence of potash at about 6 percent. The nearest source of potash for supply of South East Asia, Far-East, Australia and New Zealand is the Dead Sea where the brine is reported to contain only 2% potassium salt which is appreciably low as compared to 6% found in brine from Dhariala well. In addition to the local market, potash has great export notential as almost all our neighbouring countries import potash from sources as far as Canada.

RECOMMENDATIONS

The results of geological and geophysical investigations were correlated with the data available from A.O.C. well log. This revealed that a large brine reservior exists with the apex at the site of A.O.C. well. After evaluation of compiled data, it appeas that Dhariala Potash brine deposit is a promising prospect warranting further work and that there is every likelihood of encountering potash brine in commercial quantity. In order to confirm this and to ascertain the reservior area alongwith the rate of flow and pressure of brine, three boreholes would need to be drilled up to a maximum of 5,000 feet to encounter potash bearing horizon of brine. The drilling equipment should be so designed as to resort to solution mining if automatic pressue ceases to exist at any stage.

In spite of constant and concerted efforts it has not been possible to procure foreign technical assistance in the form of technical knowhow, equipment and funds for implementing the project although negotiations in this behalf are continuing. On the other hand, potash has a bright future both on national and global levels due to its importance in the manufacture of potash fertilizers. In addition to local consumption, it has great export potential to neighbouring countries like China, India, Sri Linka and Bangladesh and East Asian countries like Malayasia, Indonesia, Philippines and Korea.

In view of the foregoing following recommendations are made :—

(i) A.O.C. well may be reopened.

(ii) Three additional wells may be drilled.

(iii) Federal Government may place adequate funds at the disposal of Punjab Government to enable Punjmin to implement the project as mentioned at (i) and (ii) above.

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THE ROLE OF THE OIL AND GAS DEVELOPMENT CORPORATION IN THE SERVICE OF THE NATION

BY

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Abstract : *The various developments made by Oil and Gas Development Corporation from the time of its origin in 1961 till late are described. During this, the various drilling activities made by the Corporation are also described.*

The history of exploration for oil in the territory now comprising Pakistan is very old. The first well drilled for oil was in Khundal west of Mianwali in 1866 which happens to be only seven years after the poineer Drake Well of Pennsylvania in U. S. A. However, the early wells were drilled close to oil seeps and were shallow.

The first well drilled on scientific basis was at Khaur in District Attock. This well discovered oil in 1915. Till 1947, three more oilfields namely Dhulian, Joya Mair and Balkassar had been discovered. All these finds were by the Attock Oil Company.

In the first eight years after the inception of Pakistan only two oil companies namely Attock oil and Burmah oil, both of British origin were exploring for oil. During this period they drilled ten wells and discovered three gas and one oilfield. In the year 1955 started an era of rapid exploratory activity by the introduction in this field of some international oil companies like Shell, Stanvac, Hunt oil, Sun oil and Tidewater. In this phase which lasted till 1962, 39 exploratory wells were drilled which resulted in the discovery of only two gas fields. Due to these discouraging results the international oil companies shifted their activities to places outside Pakistan.

This situation was detrimental to the interest of Pakistan. Therefore in the later half of 1961, the Oil and Gas Development Corporation was formed and soviet technical and financial assistance was obtained for the search for oil.

Within three months of its formation OGDC had started practical work by sending geological, gravity and seismic parties in the field.

OGDC embarked on an extensive field surveys programme and raised six geological, three gravity and six seismic survey parties. These parties started work for the selection of immediate drilling targets as well as regional studies for the identification of the promising areas This was for the first time in the history of Pakistan that so extensive and well planned exploration for oil and gas had been undertaken.

These efforts bore fruit as the very first deep well drilled by OGDC in 1964 at Toot discovered oil. This discovery had come nearly 10 years after the last oil discovery and put new life in the exploratory efforts in Pakistan.

Alongside its activities in the oil proved region of Potwar, OGDC moved to those areas where other oil companies had either not worked or worked and failed. Working with national spirit and sound scientific reasoning OGDC discovered three gasfields in Karachi and one gas and one condensate field in Safed Koh near Dera Ghazi Khan.

In the process of these activities OGDC had developed a large workforce of highly qualified and trained professionals in all disciplines of the oil and gas exploration, drilling and production. However their handicap was rather old type of equipment which lacked both the precision and the speed. Modernization had therefore become an urgent requirement.

To meet this urgent need, in mid-seventies OGDC embarked on the modernization of its equipment with the technical and financial assistance of the western countries.

The most important improvement was in the domains of seismic survey and drilling. In seismic survey the outdated single fold technique was replaced by multifold digital recording survey and for the interpretation of this data a specialized seismic computer was installed. On drilling side four modern American drilling rigs were acquired.

These improvements had their due effect. Whereas on one hand the delineation of the subsurface structures became more precise, their drilling became faster. In the years that followed OGDC discovered a major gasfied at Pirkoh and undertook the development of Toot, Dhodak and Pirkoh fields.

The concerted efforts of OGDC have resulted in the finalization of number of structures for drilling. However, the paucity of material resources did not allow OGDC to undertake the drilling of all these structures on its own, therefore, in the interest of the self-sufficiency in oil at the earliest possible eight structure have been offered to other oil companies for drilling under joint venture.

Recently the geological and analytical laboratories of OGDC have been modernized and the process in continuing. OGDC also established a research department which has carried out a number of specialized geological, geochemical and geophysical studies with foreign collaboration for the identification of promising areas for further exploration.

As regards the offshore exploration, total eight wells have been drilled by foreign companies of which the last one was in 1978. OGDC carried out an in-depth study of the offshare prospects and then selected four most promising structures for detailed seismic survey which was later carried out with the financial assistance of Norway in Jnne 1982. It is hoped that a new phase in offshore oil exploratinn will commence soon.

To sum it up, OGDC after its inception in 1961 has carried out well planned and systematic exploration and is presently deploying most sophisticated studies and equipment in its effort. On drilling side, it has to-date drilled 19 exploratory and many more development wells. It has discovered one oil, one condensate and five gasfields. The success ratio is therefore one find in less than three wells which is far above the worldwide success ratio. This is no small achievements in itself but it is hoped that by the grace of God and the devotion of its workers, OGDC will achieve further success and make Pakistan self sufficient in its requirement of oil and gas.

As the easy pools of oil and gas are becoming increasingly rare, the approach to oil exploration needs to become increasingly sophisticated. We at OGDC are trying to keep pace with the advancements in technology and it is for the universities to keep pace with the advancements in the science of geology and related subjects. The importance attached to this factor in the development of mineral and hydrocarbon resources of Pakistan can be well-judged by the presence of the respected Chairmen of OGDC and the Pakistan Mineral Development Corporation in the Seminar.

COAL

BY

S. TAYYAB ALI

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Abstract : *Coal is a combustible rock that has its origin in the accumulation and decomposition of vegetation. The principle cumbustible element in coal is carbon.*

Vegetation which results in the formation of Coal, grows in situation where the remains of dead plants can accumulate without the normal decay by atmospheric oxygen, fungi and bacteria.

Origin of various types of coal has been discussed in detail. A review of the coal deposits of Pakistan has been given and present reserves have been calculated. Chemical anlysis of lignitic coal fields of various provinces of Pakistan has been given.

Modern uses of Coal has been mentioned in detail.

DEFINITION

Coal may be defined as a cumbustible rock. The principal combustible element in coal is *Carbon.* The different varieties of coal depend partly on the plant materials from which they are formed and partly on the physical and chemical processes they have undergone through millions of years of geological history.

Origin

Vegetation which results in coal, must grow in situation where the remains of dead plants can accumulate without the normal decay by atmospheric oxygen, fungi and bacteria.

In the formation of peat the layers of partly decayed plants change into a dark brown or black mass, having lost much of their combined oxygen by action of bacteria. Some of the plant tissues such as roots and stem fibres are still recognisable, but much of the cellulose and lignin is changed into dark colloidal liquids.

Petrification takes place in deeper stagnant water where the finer plant debris such as pollen grains, spores, unicellar algae and wind blown leaves acumulate in the complete absence of oxygen. Here they are worked on by anaerobic bacteria with the release of various bog gases and together with fine mud they make a slimy black deposit called 'Sapropel' which is richer in hydrocarbons than peat and is quite structureless.

Humic coals are brighter and shiny when they consist of soft laminated substance called *'Clarain'*, but dull when composed of harder substance called *'Durain'*.

Sapropelic coals are less common than humic coals. They are tough and hard, and break with conchoidal fracture. They are sub-divided into *'Cannel'* and *'Boghead'* coals. Cannel coals consist largely of minute fragments of vitrinite with small particles of resinous substance containing volatile hydrocarbons. These burn with a bright flame and give us the name *'cannel'* from candle.

Boghead coals are made like cannels, but contain abundant remains of algae which make them rich in hydrocarbons. Bnghead coals known as '*torbanite*' consist almost entirely of algae and yield more than 90% of volatile matter on distillation. The sapropelic coals are valuable as source of tars, oils, and coal gas.

Grades of Coal

Grading of coals is done according to the degree of alteration they have undergone from the original vegetable matter. In effect this grades them in ascending order of their carbon content, an arrangement that is commercially more useful. Four classes are recognized on this basis :—

(a) Brown Coal or lignite.
(b) Sub-Bituminous.
(c) Bituminous.
(d) Anthracite.

Brown coal is very little changed from the original peat. It contains slightly more carbon and a considerable portion of water, which can be reduced by air drying. Lignite is similar but rather more carbonised, and both may be either brown or black.

Sub-bituminous coals are black and may be regarded as either good quality lignites or poor quality bituminous coals. They include cannel coals. In the lower ranking bituminous coals, the proportion of carbon, the chief peat producing element in combustion, is higher but still more than 70% and carbon compounds amount to 30% to 40%. These can be distilled to yeild tars, oil and town gas, leaving coke as a residue.

The high ranking bituminous coals contain 20% to ?0% ot hydrocarbons and proportionately more free carbon. General household and industrial coals fall in this group.

The anthracites contain less than five percent of hydrocabons. They burn with intense heat and very little smoke of flame and are required for the furnaces of special heating plants.

Resources

The oldest coals are found in Bear Island, U.S.S.R. These are of cannel type. They are formed from algae, bacteria, and a few primitive land plants, 320 million years ago.

Most great coalfields of the world, are of Carboniferous time, 250 million years old. Their vegetation consisted chiefly of giant club-mosses, tree-ferns, horsetails and fungi. Two third of world's supply of coal comes from these coalfields. They are found in Britian, Belgium, France, Germany, U. S. A., India China, Australia and South Africa. The ensuing Permian period produced coals in Australia, India, China, South America, South Africa and parts of Europe.

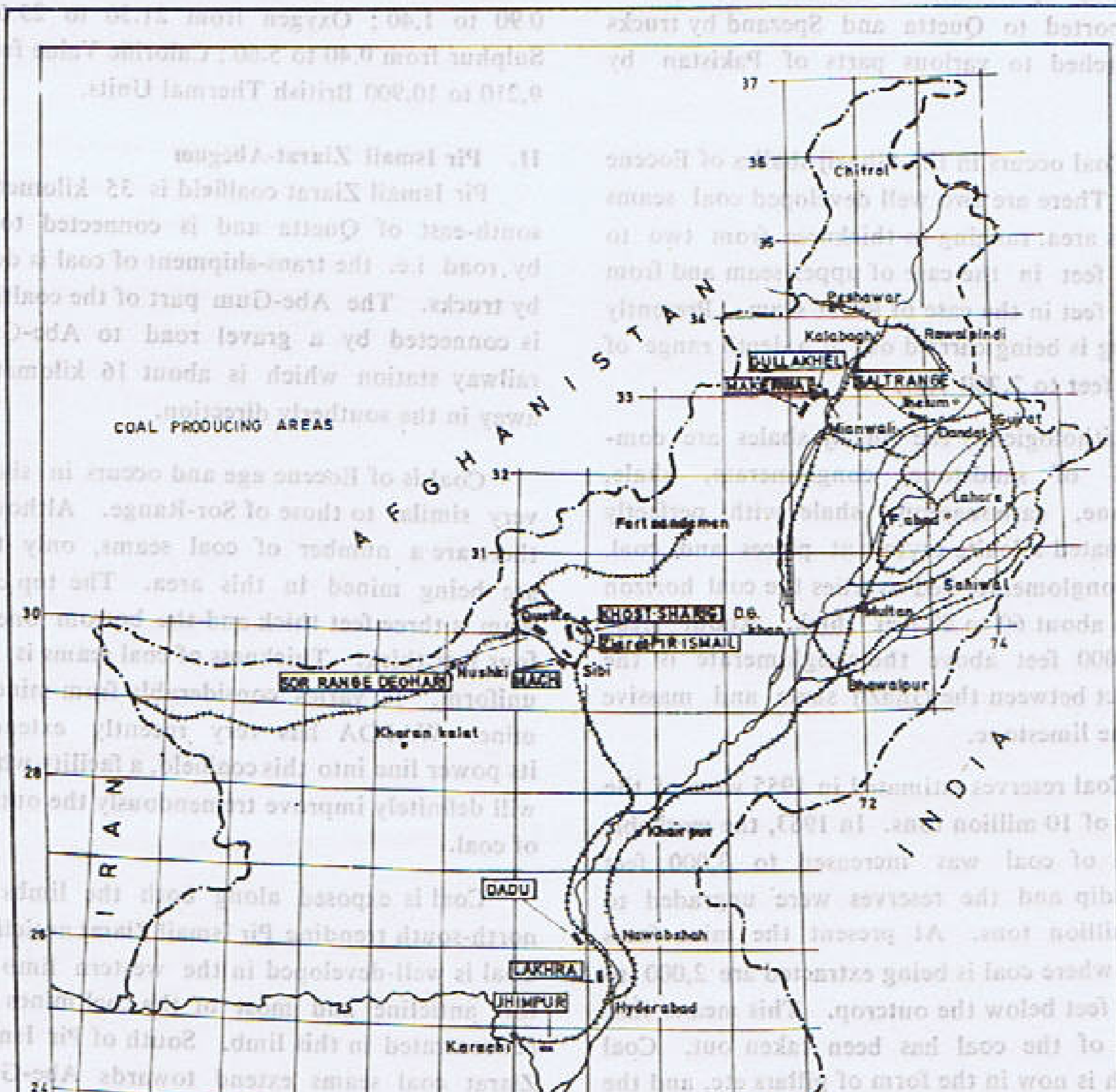
Coals younger than this are generally of poor quality and occur in lesser massive forms. These include Triassic coals in Germany, U S A., China, Japan. Jurassic coals are found in Japan, U.S.S.R., U.S.A., Mexico, Britain, Iran and Afghanistan. These are 150 million years old.

Cretaceous coals, about 100 million years old, occur in Germany, U.S.A., and Japan. The recently found commercial coals are the Tertiary brown coals and lignites of Germany, Hungary, U S. S R , U. S. A., New Zealand, Britain, The vegetation of these coals is about 60 million years old and essentially of modern type.

Coals found in Pakistan are of Paleocene to Eocene in age and are 75 to 70 million years old. These coals fall in the lignite or brown coals category. They are described below :

Baluchistan

I. Sor-Range—Deghari Coalfield. Sor-Range coalfield is about 25 kilometres from



Map of PAKISTAN, SHOWING PRINCIPAL COAL PRODUCING AREAS

Quetta railway station and is approacheable by a surfaced road which swings around the entire Sor-Range-Deghari coalfield and joins it on the southern side with the Spezand railway station. All the coal mines are connected with this Coal Highway by fairweather feeder roads. Coal is transported to Quetta and Spezand by trucks despatched to various parts of Pakistan by train.

Coal occurs in the Ghazij shalles of Eocene age. There are two well developed coal seams in this area, ranging in thickness from two to three feet in the case of upper seam and from 3 to 5 feet in the case of lower seam. Presently mining is being carried out at a depth range of 1,500 feet to 2,200 feet.

Lithologically the Ghazij shales are composed of sandstone, conglomerate, shale, siltstone, carbonaceous shale with perfectly terminated selenite crytals at places and coal. The conglomerate bed overlies the coal horizon and is about 60 to 80 feet thick. About 1,200 to 2,000 feet above the conglomerate is the contact between the Ghazij shale and massive Eocene limestone.

Coal reserves estimated in 1955 were of the order of 10 million tons. In 1963, the workable depth of coal was increased to 3,000 feet downdip and the reserves were upgraded to 53 million tons. At present the mine faces from where coal is being extracted are 2,000 to 2,200 feet below the outcrop. This means that most of the coal has been taken out. Coal which is now in the form of pillars etc. and the untouched reserves lying below 1,500 feet to 3,000 feet. It is already becoming uneconomical to extract coal from 2,200 feet depth unless the mining methods are brought on modern lines The left over reserves in this field would be hardly 7 to 8 million tons.

Samples of coal collected by an American team of geologists and analysed at the loboratories of the U.S Bureau of Mines give a percentage range of Moisture from 12.80 to 21.70 ; Volatile matter from 31.00 to 39.80 ; Fixed Carbon from 36.50 to 41.60 ; Ash from 2.70 to 13.30 ; Hydrogen from 5.50 to 6.50 ; Carbon from 51.20 to 61.50 ; Nitrogen from 0 90 to 1.40 ; Oxygen from 21.30 to 29.60 ; Sulphur from 0.40 to 5.60 ; Calorific Value from 9,210 to 10,900 British Thermal Units.

II. Pir Ismail Ziarat-Abegum

Pir Ismail Ziarat coalfield is 35 kilometres south-east of Quetta and is connected to it by road i.e. the trans-shipment of coal is done by trucks. The Abe-Gum part of the coalfield is connected by a gravel road to Abe-Gum railway station which is about 16 kilometres away in the southerly direction.

Coal is of Eocene age and occurs in shales very similar to those of Sor-Range. Although there are a number of coal seams, only two are being mined in this area. The top coal seam is three feet thick and the bottom one is four feet thick. Thickness of coal seams is not uniform. It varies considerably from mine to mine. WAPDA has very recently extended its power line into this coalfield, a facility which will definitely improve tremendously the output of coal.

Coal is exposed along both the limbs of north-south trending Pir Ismail Ziarat anticline. Coal is well-developed in the western limb of this anticline and most of the coal mines are concentrated in this limb. South of Pir Ismail Ziarat coal seams extend towards Abe-Gum area and northwards these merge into the Khost-Sharigh-Harnai coalfield near Khost ; westwards of Pir Ismail Ziarat the coalfield is very productive and extends towards the Sor-Range coalfield but has been cut off by heavy faulting in the south and also in the north.

Taking an average strike length of coal seam as 10 miles, average thickness of coal seam as three feet, workable depth downdip as 1,000 feet and the tonnage factor as 18 cubic feet per long ton, the reserves will be of the order of 9 million tons, in the Pir Ismail Ziarat coalfield.

Coal seams in the Abe-Gum area of the coalfield are very much disturbed due to acute folding and faulting. The continuity of coal seams strikewise and downdip is badly hampered alongwith thickness of the coal seams A number of years of mining in this area has produced discouraging results. It is very difficult to arrive at any authentic figure of reserves in this part of the coalfield unless the area is geologically mapped in detail and is followed up by drilling. A rough figure of reserves will, however, be of the order of 2 million tons.

III. Mach-Bolan Coalfield

The Mach-Bolan coalfield lies at the southern entrance of the Bolan Pass and is almost mid-way between Quetta and Sibi. The coal field is situated on both sides of the railway line and also under it. All the mines are accessible by gravel roads and are within five to six miles of the Mach railway station of the Pakistan Railways. The Quetta-Karachi National Highway No. 25 passes through the coalfield.

Coal occurs in the form of numerous thin coal seams out of which only two are economically mineable, although a third one is tapped here and there depending on its thickness. The thichness of coal seams ranges from a few inches to four feet. The area is structurally much disturbed due chiefly to its situation at the seaward edge of the Ghazij shales delta at the time of coal deposition and the intense syntaxial deformations taking place in and arround it.

The coal field occupies an area of thirty square miles. It is traversed with closely spaced folds and faults. The coal seams are associated with 'anastomosing' stringers of gypsum. The reserves are of the order of 15 million tons out of which more than half has been mined out and the rest is held up in the form of pillars and partly in the areas which are still untouched by the existing mines and partly in those areas which have not as yet been explored.

Chemical anylysis on the average indicate the percentage variation of Moisture from 7.10 to 12.10 ; Volatile Matter from 34.50 to 39.40 ; Fixed Carbon from 32.40 to 41.50 ; Ash from 9.60 to 20.30 ; Sulphur from 3.20 to 7.40 ; and Calorific Value from 9,200 to 10,300 British Thermal Units.

IV. Harnai –Shariagh –Khost Coalfield

This coalfield is the largest and the oldest single coal-field of Baluchistan. The Sibi-Zardalu section of the Pakistan railways passes along the northern edge of the coalfield and terminates at Zardalu railway station. A fair weather gravel road connects the coalfield from Khost via Chapper Rift and Kach to Quetta. The road follows the abandoned railway track of the Pakistan Railways. This was the original route of the railway line connecting Quetta to Sibi before it was abandoned due to the collapse of the railway tunnel through the Chapper Rift. The Harnai end of the coalfield is connected by surfaced road with Loralai and onwards to Dera Ghazi Khan via Fort Munro to other cities of the Punjab.

The coal bearing formations extend from Chapper Rift in the north-west to Harnai in the south-east over a distance of 35 miles or 56 kilometres. The coal seams steeply dip southwest and form in the middle and south-eastern parts of the coalfield synclinal and faulted anticlinal folds.

Workable coal seams in this coalfield are three, i.e. Upper seam, Middle seam and Bottom seam, which are 2′ to 2′9″, 2′ to 2′6″ and 1′/6″ to 2′ thick respectively in the Sharigh area. In the Khost area the top seam is worked which averages three feet in thickness, and in Harnai area where also the Top seam is worked, the thickness on the average is two feet.

Mining activities in the Khost and Harnai areas are almost at the minimum due partly to thinning of the coal seams and partly to the mining having reached a depth wherefrom extraction of coal is not profitable. The area on the south, from three miles south of Sharigh to seven miles southeast of Sharigh is however promising. The Pakistan Mineral Development Corporation have proved that after washing, coal, from this area, improves its coking properties and is usable by mixing it with the imported coke on a ratio of 20 : 80, for preparing a feed for the blast furnace. For this purpose the first washery of the country has been installed to wash about 100,000 tons of coal annually to supply 75,000 tons of washed coal to the Pakistan Steel Mills Ltd., at Karachi.

Near Harnai a new seam is developed. It is three feet thick and is mined. The Sharigh seams extend to Harnai area but are not being worked.

The chemical analysis indicate the percentage variation of Moisture from 4.00 to 11.00 ; Volatile Matter from 34.80 to 45.30 ; Fixed Carbon from 25.50 to 43.80 ; Ash from 9.30 to 34.80 ; Sulphur from 5.10 to 7.11 ; Calorific Value from 8,600 to 12,400 British Thermal Units.

Reserves of coal of all categories in this coalfield are of the order of 25,000,000 tons. These were estimated in 1954 as 15 million tons and in 1974 as 40 million tons.

V. Duki Coalfield

Duki coalfield is situated about two miles southeast of Duki Tehsil building to about eight miles west of it, in the Loralai District. Duki is fifteen miles south of Loralai and connected by a good road to it and also to Quetta.

Coal occurs in the middle Ghazij shales of Eocene age. Middle and lower zones of Ghazij shales are well developed in a large syncline. Earlier workers after examining the surface exposure of coal considered it of poor quality and quantity. But recent detailed developments have opened up a promising coal field in the centre of this syncline. In depth coal has improved both in quality and reserves which may be of the order of five million tons.

Coal seam is three feet thick on the average. It dips 35 degrees towards north. It is associated with grey silty shales lignitic sulphurous shales, sandstone and shelly beds.

A thermal electric plant is planned to be installed at Duki, which will use local Duki coal as its fuel. This coal field being nearest to the Punjab, coal is being transshipped to the Punjab areas by trucks.

VI. Chamalang –Bahlol—Bala Dhaka Coalfield

Coal in Chamalang was first reported by Sir R. Sandemane in 1870. Coal was classed as of good quality and the average thickness was recorded as 9 inches. The author examined the Chamalang area in 1948 and reported the occurrence of three coal seams, each about a foot thick, occuring over a lateral distance of six miles between Bahlol and Chamalang. M.I. Ahmad examined the Bala Dhaka—Bahlol area in 1945 and described the coal seams alongwith their occurrences in other adjacent areas namely Nosham, Bahadur Siah and Khojal Dab.

Coal occurs in the Ghazij shales of eocene age. The strarta are folded into anticline and a syncline. The coal bearing zone is about 300 to 400 feet thick and fairly prospective. Dips are 45 degrees. Reserves would be of the order of five million tons. The basis being a single seam three feet thick on the average extending for six miles along the strike and extending 1000 feet downdip, with tonnage factors as 18 cubic feet equal to one ton.

Chemical analysis got done by M.I. Ahmad gives percentage range of Moisture from 7.90 to 11.84 ; Volatile Matter from 34.94 to 38.46 ; Fixed Carbon from 31.02 to 51.14 ; Ash from 1.64 to 29.24 ; Sulphur from 3.33 to 4.54%.

North West Frontier Province

There is no coal deposit of commercial significane in the North West Frontier Province except the coal seams of Mianwali District which run down the dip into the Kohat District from the crest of Surghar Range on the top of which runs the boundary between the N.W.F P. Province and the Punjab. As the coal seams extend into Kohat district the overburden is thousands of feet thick and hence cannot be worked by driving a vertical shaft. There is however one point in the Baroch Gorge where the coal outcrop is two feet thick and this point lies in the Kohat District. In case provincial government is keen to develop their own coal mines the area around the outcrop would have to be mapped geologically in details.

Sample collected from the coal outcrop of Baroch gorge of Kohat district gave Moisture 5.20% ; Volatile 33.26%; Fixed Carbon 36 27%; Ash 16% ; Sulphur 9.2 %.

Punjab

The producing coalfields of the Punjab are confined to the areas comprising Cis-Indus and Trans-Indus Salt-Range which are described as follows :—

1. Cis-Indus Salt-Range Coalfield

Cis-Indus Salt-Range coal deposits are of late Paleocene age. The vegetation and forests of the Cis-Indus Salt-Range areas were burried by sediments during late Paleocene period. This coal-bearing formation is called Patala Formation. The formation consists of shale, marl with subordinate limestone and sandstone. The coal seams of the formation are locally known as Dandot coal seams. The formation is rich in fossils which comprise foraminiferas, molluscs and ostracodes.

There are two coal seams ranging in thickness from 3.9 inches to 4 92 feet (10 centimetres to 1.5 metres). Coal has been classified as lignite with high and variable hydrogen, ash and sulphur content. The coal horizon underlies areas totalling hundreds of square miles north of the Salt-Range scarp facing the Jhelum plains. Under the plateau north of the scarp, coal is found at a depth of 246 feet to 295 feet (75 m. to 90 metres) in the east between Bhaghanwala and Dandot and 350 to 450 feet (106 m. to 137 metres) below plateau's surface in the west of Dandot upto and beyond Katha.

Chemical analysis gave Moisture ranging from 5 10 to 7.23% ; Volatile Matter from 36.26 to 43.98 ; Fixed Carbon from 31.04 to 48.91% ; Ash from 6.00 to 25.74% ; Calorific Value from 6,383 to 11,500 British Thermal Units ; Sulphur from 3.5 to 11.40%.

Coal reserves in the Cis-Indus Salt-Range were estimated in the year 1954, as 75 million tons. Coal extracted from this field would be about ten million tons, the left over reserves would be 65 million tons. These reserves include areas proved by drilling five to six miles away from the scarp under the Plateau limestone.

2. Trans-Indus Salt-Range Coalfield

The Trans-Indus Salt-Range coal deposits are of early Paleocene age. The coal bearing formation of this coalfield is known as Hangu Formation. This formation in the Salt-Range area consists of dark grey sandstone, shale, carbonaceous shale, coal and nodular argillaceous limestone. A two to three metres thick bed of ferruginous, oolitic pisolitic sandstone is found at the base of the formation.

The coalfield has been divided into two distinct areas i. e. Makerwal and Gullakhel. The Gullakhel area extends from Mallakhel to Chapri over a distance of about twenty miles. Most of the coal from this area has been extracted upto the boundary of North West Frontier Province.

The Makerwal coal deposit is spread over a strike distance of about six miles. Thickness of the coal seam ranges from less than a foot to 12 feet. Coal mining in this area was started in 1903 and since then coal has been mined almost uninterrupted. The coalfield stands almost worked out except the quantity remaining in the form of pillars and below the low level tunnel. Mining of coal below the low level tunnel is becoming difficult and expensive due to inrush of large quantities of underground water.

Coal seam dips 30 degrees westwards into the hill. Reserves of coal estimated in 1968, as eighteen million tons upto 200 feet below the level of low tunnel.

Chemical analysis of coal gives percentage range of Moisture from 4.20 to 6.00 ; Volatile Matter from 37.10 to 44.90 ; Fixed Carbon from 36.00 to 44.00 ; Ash from 7.00 to 21.00; Sulphur from 4.00 to 5.60 ; and Calorific Value from 9,550 to 11,850 BTU.

Sind

There are two distinct horizons of coal in the Sind province. Coal is being mined from both these horizons on commercial scale. Coal found in the younger horizon is of early Eocene age and that found in the older strata belongs to Paleocene age. Coal of a first horizon is being mined at Jhimpir and Meting areas and will be described below under the caption 'Jhimpir-Meting coalfield'. Coal of older period is being mined in Lakhra area and will be described under the heading 'Lakhra Coalfield' yet another important coalfield has been reported from Thatta area and will hereinafter be described under the caption 'Thatta Coalfield'.

I. Jhimpir—Meting Coalfield

Coal occurs in the Sonahri Member of Laki Formation of early Eocene age. The coal bearing strata are exposed at the base of a low scarp of Laki limestone which trends irregularly northeast from Sonahri Dhand along a line roughly parallel to the Karachi-Lahore main railway line of the Pakistan Railways. Coalfield is situated about 80 miles north-east of Karachi and is approacheable both by railway and road.

The coal bearing Sonahri beds are composed of variegated clays calcareous and ferruginous sandstone, limestone with layers of limonite. The strata dip westwards at less than 5 degrees, coal seam ranges in thickness from nine inches to five feet.

Reserves of coal were considered to be of the order of ten million tons ; these were raised to 25 million tons by increasing the workable depth to about two miles and in the year 1969 the reserves were upgraded to a figure of 28 million tons. About one third of these reserves appear to have been mined out during the past forty years.

Chemical analysis indicated Moisture ranging from 26.80 to 29.80 ; Volatile Matter from 29.80 to 52.30 ; Fixed Carbon from 31.00 to 51.50 ; Ash from 8.20 to 10.65 ; Calorific Value 7,400 to 11,900 British Thermal Units.

II. Lakhra Coalfield

Lakhra coalfield is about 30 miles from Hyderabad and 125 miles by road from Karachi. It is located in the Dadu District of Sind. Coal was discovered in this coalfied in the year 1857 in a shaft sunk at Laibyan a depth of 64 feet in rocks belonging to Paleocene age. The coalseam met with in this shaft was five feet nine inches thick and found to thin out in all directions.

Coal occurs in Bara Formation, composed of variegated gypseous shales, sandstones, siltstones and carbonaceous shales with a number of coal seams. Coal seam which is being mined is known as Lailyan Coal Seam.

Lailyan coal has been classified as quality lignite having dull black streak. It contains irregularly distributed pyrite and resin. Sulphur content is high. Gypsum is associated with coal. Coal has a specific gravity of 1.25 to 1.57. On exposure to air it catches spontaneous fire. Coal beds are lying horizontal and having been proved to exist in an area of 100 square miles or more.

The starta are exhibiting a structure of elongated dome with its longer axis trending in a north-south direction. The total length of this fold is about sixty miles, from Sehwan in the north to Ochhri in the south.

Proved reserves of coal in an area of 80 square miles are of the order of 240 million tons. Total area of dome in which the existance of coal is fairly certain would be two hundred square miles. The probable reserves would therefore be of the order of 500 million tons.

Average chemical analysis gives the percentage rang of Moisture from 5.50 to 35 70; Volatile Matter from 28.00 to 54.00; Fixed Carbon from 25.80 to 51.00; Ash from 9.00 to 27.00; Sulphur from 2.10 to to 9.90; Calorific Value from 7,010 to 13,040 British Thermal Units.

III. Thatta Coalfield

The Burmah Oil Company drilled a number of bore holes in search for oil and gas during 1940, across the Indus Delta from the neighbourhood of Thatta towards Karachi. The one nearest to Thatta encountered four feet of lignite at a depth of 940 feet. On the basis of this information probably the Geological Survey of Pakistan drilled one bore hole at Sonda, close to Bhutto Model Town at Thatta in the exposed lower Ranikot or Paleocene strata and discovered a coal bed four feet four inches thick at a depth of 385 feet. Coal thus discovered by the Geological Survey of Pakistan was given wide publicity in the press and was even estimated to contain a mineable reserve of 1000 million tons.

This find definitely opens up a new area fairly close to Karachi hence needs to be explored with fervour for a rapidly developing Pakistan in which the energy from hydel projects have failed to meet the country's requirements.

Chemical analysis of coal obtained from the bore drilled by G.S.P. at Sonda give the percentage range of Moisture from 14 to 15 Volatile Matter from 43 to 44; Ash from 11.00 to 11.15; Fixed Carbon from 30 to 32; Sulphur from 0.70 to 0.80.

USES OF COAL

Coal is used as an industrial fuel for heat, power, and as a source of coke which is used in the blast furnace to produce iron, an extremely important metal of modern age. In many countries lignite is burned in large quantities to produce gas on commercial scale for domestic consumption and heating of offices, business houses etc, in large cities where gas deposits are not available.

The water gas produced by the action of steam on incandescent coke, serves as a wide range of chemicals and synthetic chemicals. Coal tar a byproduct of this gas is used extensively in the chemical and dye industry.

Low temperature carbonisation of lignite and other low rank coals produce smokeless fuels, industrial carbon, and low temperature oils and tars. Carbonisation of lignite produces

CHAR which is used in some metallurgical processes, after-re-carbonisation and processing.

Coal is used for calcining cement, or lime, or firing ceramics materials. Its conversion to liquid and gaseous forms are other promising new fields of use of coal. One ton of coal yields 12,000 cubic feet of gas and about twelve gallons of coal tar.

Coal is used in sintering iron ore and in preparing a pre-reduced charge for the blast furnace. Oxidized lignite (*LEONARDITE*) is being used as a drilling mud additive. Lignites and bituminous coals are used after ammoniation as fertilizers. The fly ash from coal is added to concrete to make use of its pozzolanic properties, manufacture of light weight aggregates and in combination with lime as a soil stabilizer and road base material.

In Pakistan coal is used only as solid fuel mainly in bricks and lime burning, ginning factories and briquetting plant, and a small quantity of selected coal for boilers of hand fired type. A large coal fired electric plant was installed at Quetta but after it worked successfully for some years, it was closed down due to the linking of Quetta with the National Grid. An acute shortage of energy in the country can only be eased out if we expeditiously introduce electric plants based on atomic energy and coal, which still is considered by a number of developed countries as the most dependable conventional fuel.

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ESTIMATING THE AMOUNT OF SEISMIC SURVEY USING TREND PREDICTION

BY
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Abstract : *Relationship between time series of seismic survey and recoverable reserves can directly be applied to forecast the further survey requirements provided seismic and drilling efforts are linearly connected. Estimation of lag between the later two is necessary for planning. The method has been successfully applied to predict the amount of seismic survey in a case study.*

INTRODUCTION

Both geological and geophysical methods are used for the exploration of hydrocarbons. In the recent decades, the seismic survey has emerged as the most effective technique for finding structural and stratigraphic traps. Recently, direct detections of hydrocarbons using seismics are also being reported in the geophysical literature. 1980-world-wide expenditure on seismic survey was 94% of all geophysical dollars (about 3 billion US $). This resulted in the acquisition of 345,000 Km of seismic coverage. The industry morale is to increase chances of finding hydrocarbons by increasing the quantity and quality of seismic data.

Expected recoveries based upon drilling rate are forecasted by many authors. Here, we have tried to establish a rationale between the expected recoverable reserves and the amount of seismic efforts involved, using trend prediction by graphical approach. This rationale can be applied in a number of cases for planning the amount of seismic work for a basin, country or a company in combination with their future energy demands.

Theory

A typical experience encountered in an oil play is shown in Figure-1. The objective is to quantify this curve. We assume that seismics play the major role in exploration efforts.

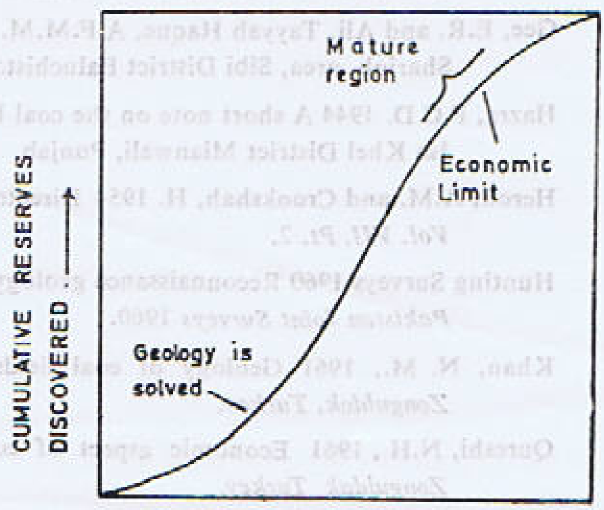

Fig. 1. Cumulative discovery effort against cumulative reserves discovered in an oil play.

Therefore, for an ideal system :

$$R(t) = f\,D(t) \qquad 1$$

$$D(t) = f\,S(t + \Sigma) \qquad 2$$

where R(t) = Total Recoverable Reserve at time t.

D (t) = Total Amount of Drilling at time t.

S (t) = Total Amount of Seismic Survey at time t.

Σ = Time lag between Seismics and Drilling activities.

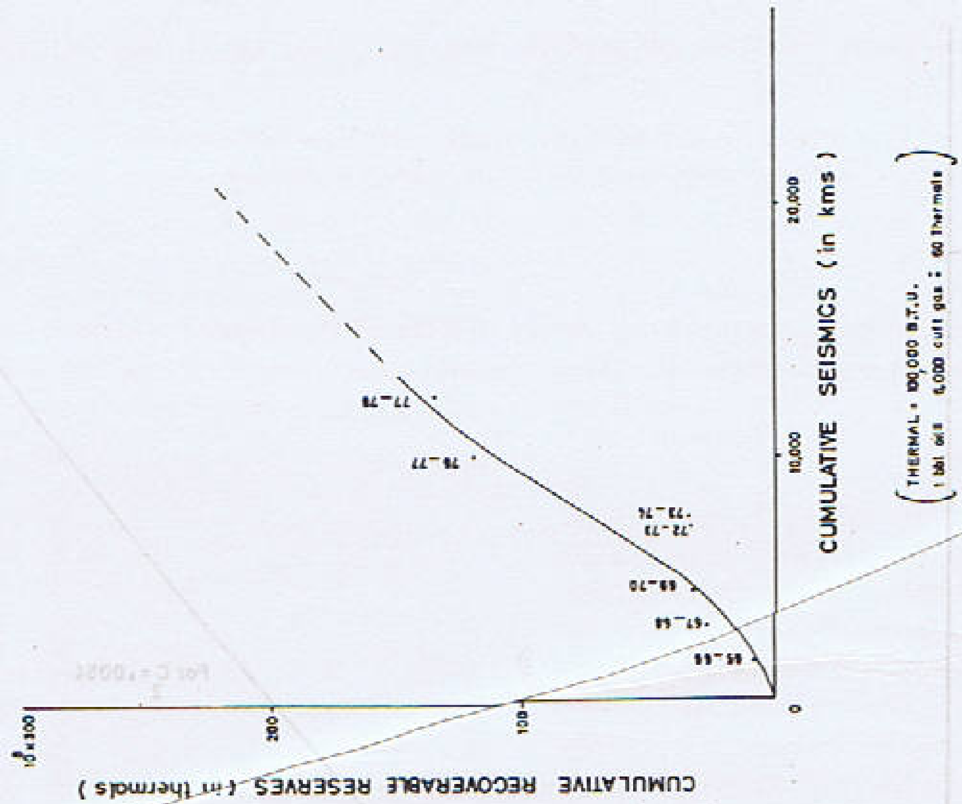

Fig-3. Relationship between cumulative seismics and cumulative recoverable reserves.

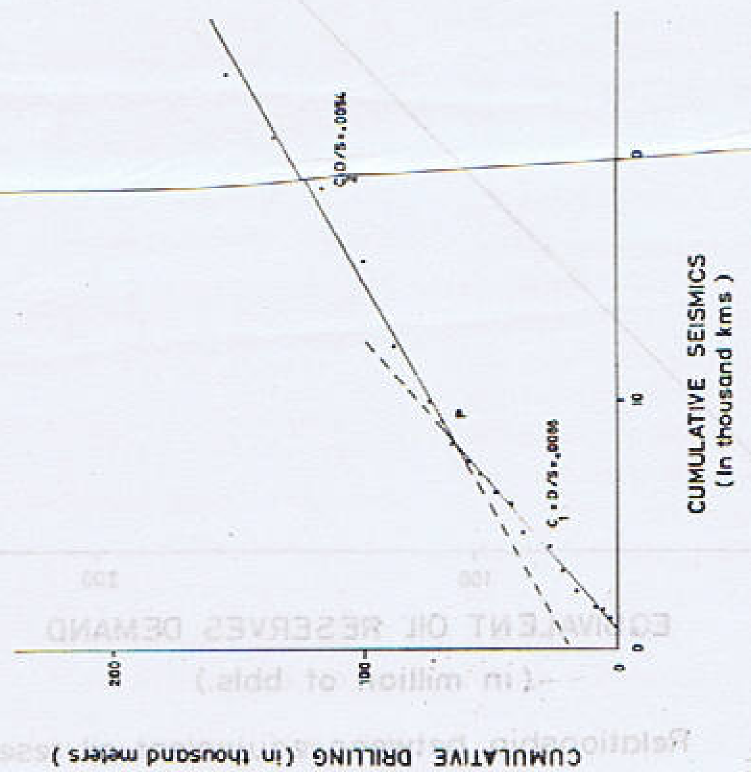

Fig-2. Relationship between cumulative seismic survey and cumulative drilling.

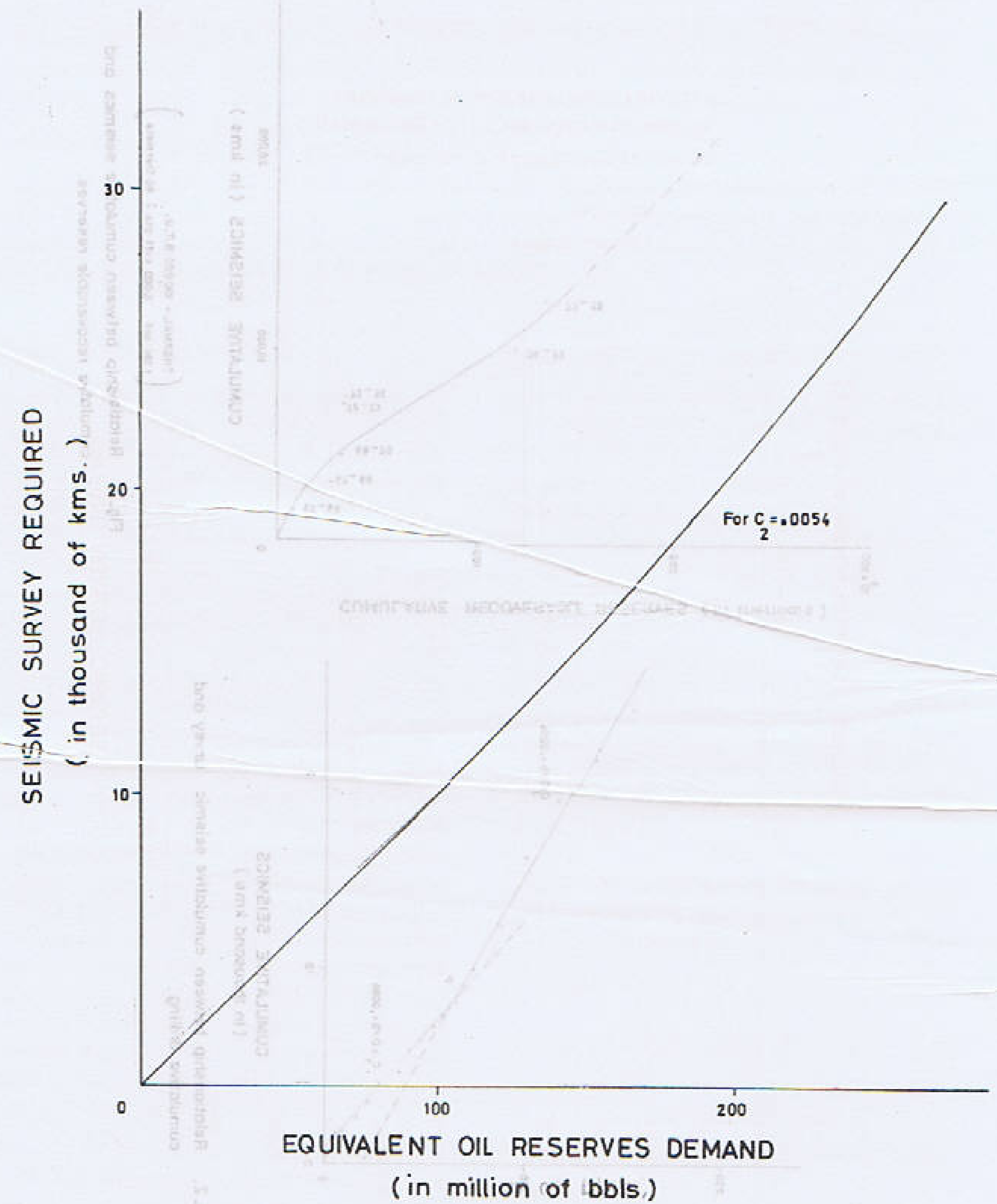

Fig. 4. Relationship between equivalent oil reserves demand and seismic survey required.

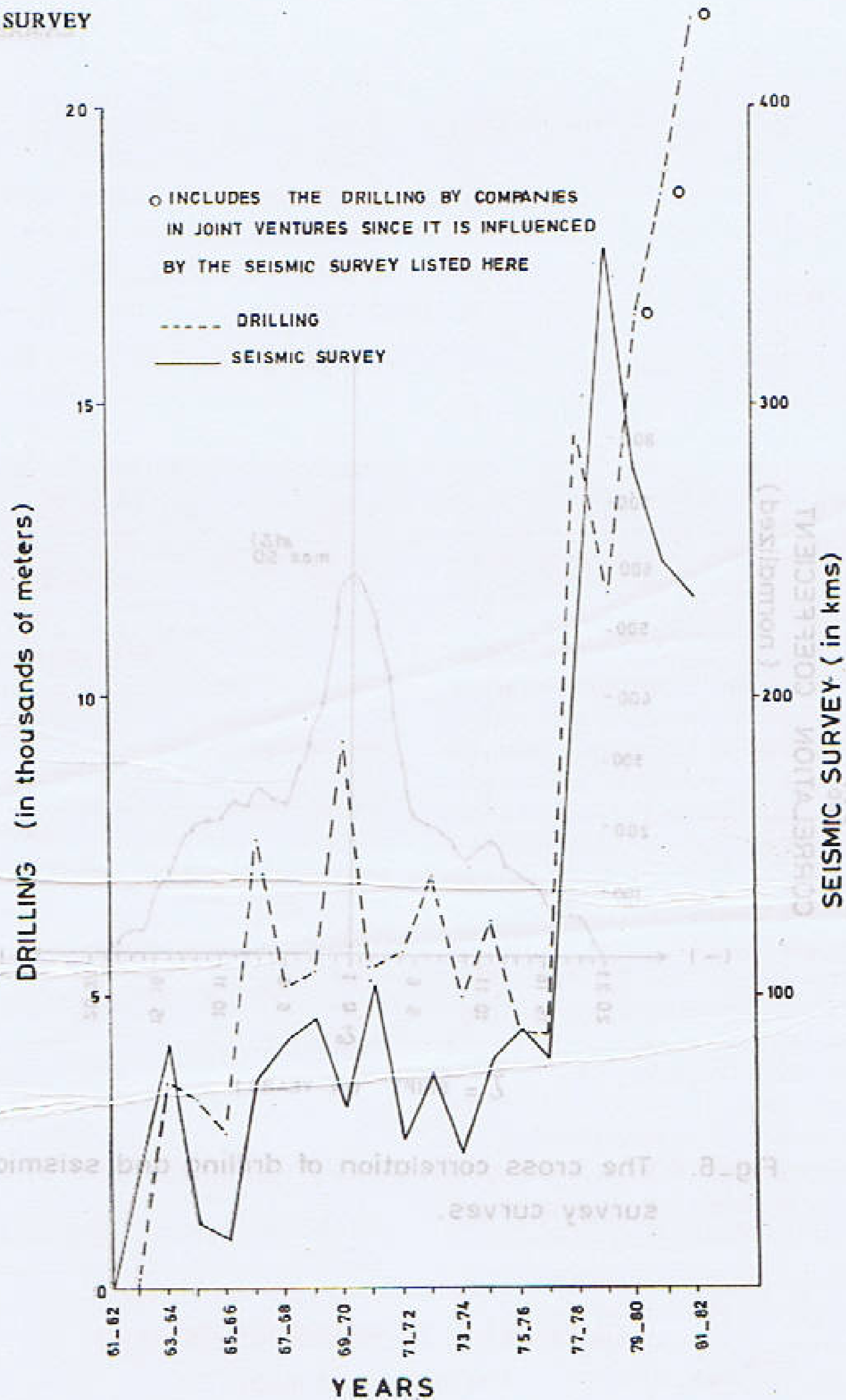

Fig. 5. Yearly sampled data of seismic survey and corresponding drilling.

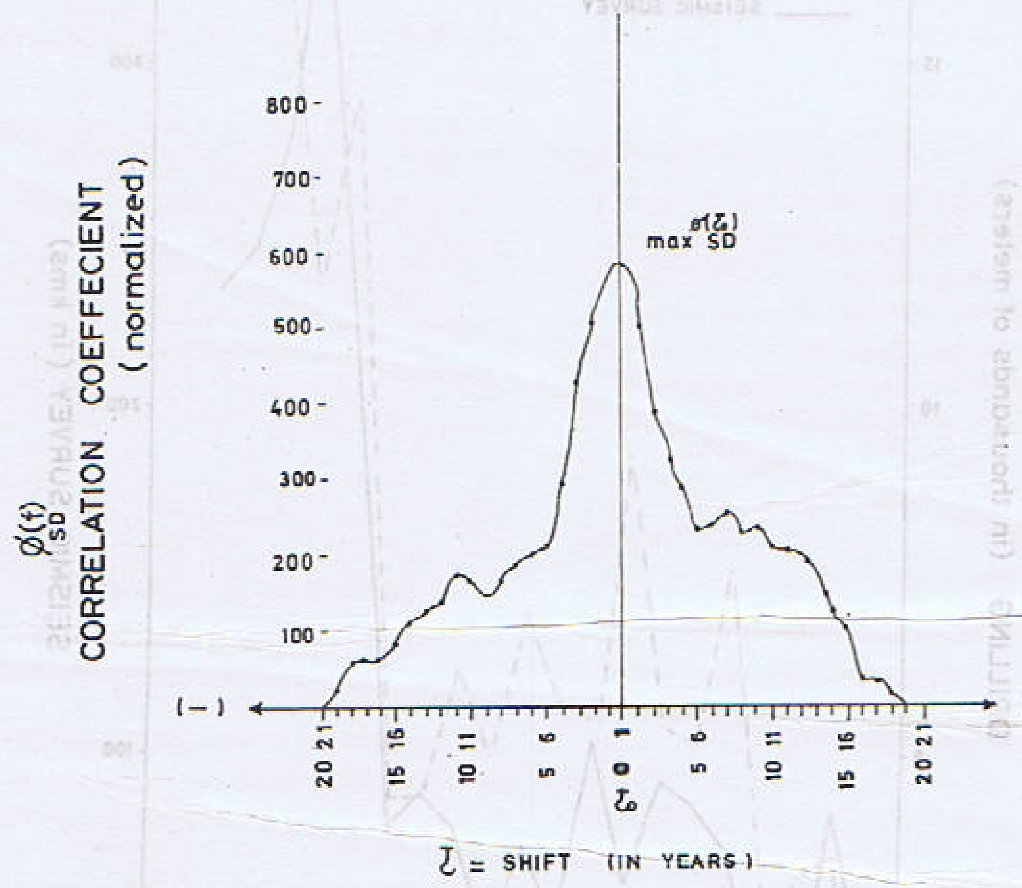

Fig_6. The cross correlation of drilling and seismic survey curves.

In order to see the effect of seismic survey on recoverable reserves, we have to firstly, establish the relationship between S (t) and, secondly, D (t) and R (t). If the relation between S (t) and D (t) is linear, we can directly relate the recoverable reserves R (t) as a function of S (t). Let us assume :

D (t)/S (t) = C, where C is a constant
then S (t).C= D (t) 3.

Substituting in eq (1) :

$$R(t) = C.\, f(S(t+\Sigma)) \qquad 4.$$

Therefore, if we plot the cumulative reserves found at a particular time and corresponding cumulative seismics, we can extrapolate the data by the method of least square and curve fitting or by graphical technique. This extrapolation will give the relationship between expected recoverable reserves and amount of seismic work needed. The subjectivity and error in the extrapolation can be reduced if the present position is roughly on the general curve of Figure-1.

To find optimum lag $\Sigma = \Sigma_o$ between S_i (t) and D_i (t), the instantaneous values of seismics and drilling, we have to cross-correlate the time series of D_i (t) and S_i (t) which is represented by :

$$\phi_{sd}(t) = \int S_i(t+\Sigma)\, D_i(t)\, d\Sigma$$

$$= \sum_{t=0}^{m+n} S_i(t+\Sigma) \times D_i(t) \qquad 5.$$

Where ϕ_{sd} (t) is the cross correlation of S_i (t) and D_i (t), sign "X" denotes the operation of cross-correlation. The time series S_i (t) has t=c, 1 . . . , . . n and D_i (t) has t=o, 1 . . . . . m number of coefficients.

The cross-correlation ϕ_{sd} (t) is a measure of similarity between time series S_i (t) and D_i (t). The shift for maximum value of $\phi_{sd} = \phi_{sd_{max}}$ will be the required optimum lag $\Sigma = \Sigma_o$

$$max\phi_{sd}(\Sigma_o) = \sum_{t=0}^{m+n} S_i(t+\Sigma_o) \times D_i(t) \qquad 6.$$

The lag Σ_o can be used while planning the amount of seismic survey.

APPLICATION

The 21 years data of S (t), D (t), R (t) sampled at 1 year was gathered from O.G.D.C. and applied to forecast the relationship between S, R. Figure-2 shows the plot of cumulative seismic survey and cumulative drilling. Two straight lines can readily be fitted with the slopes C=D/S=.0086, .0054. The point P denotes the change in the exploration philosophy. Line with C=.005 indicates comparative lesser drilling ventures than the exploration efforts since 1973-74 onwards. To settle on the old performance, drilling has to be increased substantially.

Since, the relation between D (t) and S (t) is linear, we can directly use the plot between S (t) and R (t), Figure-3 to extrapolate the trend. It is generally understood that both drilling and exploration activities in Pakistan are not mature. Therefore, the trend can be extrapolated with higher degree of confidence, for a particular value of "C". Figure-4 is the result of such an effort. It can be seen that to find 100 million bbls of equivalent oil reserves, about 10,000 Km. of seismic survey is required.

The yearly sampled data of seismic survey S_i and corresponding D_i was plotted vs time to see the correlation between the two time series, Figure-5. The cross correlation of the two curves is shown in Figure-6. The maximum correlation coefficient ${}_{max}\phi_{sd}$ (t) was found to be at a shift of 0-1 year. If we had samnled the data on monthly basis, we would have found the lag in number of months. Taking the realistic view, it can be infered that drilling D_t (t) follows the seismic S_t (t) with a lag of roughly a year. Therefore, while planning to find reserves of 100 mil'ion bbls of equivalent oil in say 3rd year, we have to distribute 10,000 Km. of survey in preceding 1st and 2nd year.

ACKNOWLEDGEMENT

The authors are grateful to Mr. M.H. Rizvi, Chairman O.G.D.C., for encouragement and permission to establish this paper. We are also indebted to Mr. Shahid Akbar, Manager (Corporate Planning) for prov;ding the basic data and co-operation.

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ROLE OF GEOLOGIST IN ATOMIC ENERGY

BY

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Abstract : *The paper deals with the role of Geologist during various stages of uranium exploration and mining processing. A brief discussion about the various conventional method, used for its exploration are also described.*

Today more than 80 Geologists of Pakistan Atomic Energy Commission are scattered from high mountains in the north to the Makran Coast searching for materials needed for our nuclear programme. In addition to Uranium our other interests include Zirconium, lithium, Beryllium and to some extant Ni and Co. Uranium of course being the major interest.

Geologists play a significant role in the Atomic Energy since they have been entrusted with the responsibility to provide the basic material needed for nuclear programmes whether it be much publicized nuclear explosions, nuclear power, radiotherapy, agricultural research or nuclear physicist's adventures in the world of Atom. Geologists play a major role in prospecting and exploration of raw material, their mining, ore processing and beyond.

Uranium is the heaviest naturally occuring element. Naturally occuring Uranium is made up of three isotopes i.e. U238, 99.28% U235, 0.74% and U234, 0.006%. Only U235 is readily fission able and complete fission of 450 grams of U 235 is equivalent to 7000 barrels of crude oil or 30,00,000 lbs of Coal. Two man made isotopes Pu 239 and U 233 can also provide energy through fission and these are created by absorbing neutrons by U238 in a breeder reactor. However, most existing reactors produce only small quantities of Pu 238 and U 233. We will probably have to depend on U 235 in natural Uranium for many years to come and hence the Geologist can be considered as the main bread winner of the Nuclear Energy family. The principal need for Uranium is for use in Nuclear Power Plants and for military requirements. However, Uranium is also important raw material in the production of various radioisotopes used in Medicine, Chemistry, Agricultural research and Industry. Uranium is also used in minor amounts as alloy addition to improve corrosive resistance and high temperature properties of steel.

The first question, therefore, any nuclear programme would confront with is where to find Uranium and thus starts the prospecting phase. Here the Atomic Energy Geologists are confronted such heavy odds as only 3 of every 3000 anomalies found will become workable deposits. Geological mapping, airborn radiometeric surveys, ground surveys, Radon in Soil and ground water, Geobotanical surveys, other Geophysical surveys followed by exploration drilling all are the traditional exploration methods and Uranium exploration is no exception to these methods. In addition, such nuclear techniques as radiogenic heat measurement, helium measurements and remote sensing are also in use. After having located the exploration, drilling, aditing etc. are conducted to deliniate the ore body.

Following exploration, during which a Uranium deposit is delineated and evaluated, the next step is to select a method to recover Uranium from the ground. Like any other ore, a variety of methods are employed for Uranium mining.

Conventional methods include

1. Open pit mining.
2. Underground mining.

Non Conventional methods are

1. Solution mining.
2. Recovery from mine water.
3. Recovery as a by-product from phosphate and Copper Operator.

Needless to say that every mining operation depends on the Geological help. The conventional methods just mentioned are no different than used for other Ores. However some unconventional methods which are being developed now will be mentioned very briefly as they are being successfully used in Uranium mining. One of these methods is known as in-situ solution mining. Uranium when in U^{+6} form dissolves readily in dilute acids and alkalies. The Ore body is drilled for injection well to pump solvent into the body and production wells for recovering the each liquor.

To use these methods, however the following conditions must be satisfied.

1. Uranium Ore body must be in horizantal.
2. Ore must occur below static water table.
3. Direction and velocity of regional waterflow must be known.
4. Mineralogy of Ore should be well defined.
5. Cost faction unit show advantage over conventional mining techniques, Ore body too small or too deep.

After the mining of Ore, the processing phase starts which converts Ore with U_3O_8 content of 0.1 to 0.2% into a compound called "yellow cake" containing about 80 to 95% U_3O_8. The design of the process will vary from mill to mill depending upon the nature of gangue and by-products, precise mineralogical definition is, therefore essential. The mineralogy of Uranium Ore fundamently determines the technology and economics of its exploitations and determines the ultimate quantitative Uranium recovery, that can be achieved by any particular process. Therefore, in planning a programme of investigation into the extraction of Uranium from any ore, a knowledge of its mineralogy and the behaviour of the Ore in particular environment is important.

Although, it is not infrequent that the mineralogist is called upon to explain the difficulties that have been encountered by a metallurgist during the course of an investigation, the adequate application of mineralogical data is seldom practised in the initial planning of an investigation into a treatment process. The metallurgist experienced in the technology of Uranium Ore processing will use his knowledge of mineralogy subconciously to define a treatment problem. Indeed the nature of his experience is an intuitive understanding of the type of treatment flow sheets most likely to pertain to the particular ore mineralogy. Perhaps for this reason, the significance of mineralogy in the development of flowsheets for the processing of Uranium Ores is often under-estimated.

Rocks are complex assemblage of minerals and differ widely in details of composition and texure so that no single ore is exactly similar to another. Samples from one ore body vary, often significantly. These differences mean that at no time can a flowsheets be realistically optimized for all likely variations, nor can the treatment flowsheet can be transferred in detail from one ore to another. A flowsheet is always a compromise of many factors and its development remains dynamic throughtout the life of a mine. A knowledge of the mineralogy of the ore, the variation of that mineralogy during the mine development and an appreciation of the behaviour of minerals and mineral assemblages form a sound basis for deciding the best compromise.

At this juncture, the raw material is delivered and scientists and engineers engaged in various aspects of nuclear fuel cycle take over while the Geologist finds his retreat into a virgin area for further prospecting.

After having made the raw material available, the next step where geologist is once again called upon is the site selection for a nuclear reactor. In addition to a number of other factor which are too numerous to be mentioned here, geology of the site is to be defind. Geological structures such as faults, fractures, joints and folds in the vicinity of the site must be thoroughly studied and their tectonic significance to the stability of the site evaluated. Faulting is an especially critical feature of a site as the probability of surface displacement at or very close to the site would eliminate a site from practical considerations.

Ground water condition of the site must also be known. The depth and direction and rate of groundwater flow must be determined. Siesmology of the area must be thoroughly investigated. This is a very important investigation and can have a considerable impact on the cost of a nuclear plant when constructed in an earthquake zone. It is necessary to establish what horizonal and vertical acceleration the plant must withstand also, what the earth quake spectrum and damping factor for the foundation must be, with potentially very important cost implications.

Now the reactor is built, the fuel is available and other disciplines will take over to play their role. Geologist is called upon once again when the waste disposal is considered. A solid granite pluton or salt dome with minimum fracturing is to be discovered to seal the highly toxic and radioactive wastes.

In a nut shell, we search for the raw material, we explore it, we help to mine it, we also lend a helping hand to process it and then handover to the engineer and scientist to further refine it, burn it and finally when it is reduced to a radioactive waste we burry it to complete the cycle. We are Geologists of the Atomic Energy Commission.

WHEN YOUR SURVIVAL DEPENDS UPON YOUR MINERAL RESOURCES, ITS DEVELOPMENT IS NEVER A LUXURY

BY

SHAH JAHAN

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Abstract : *The development of a country and future of its society depends upon its mineral resources. Pakistan has immense mineral wealth and society should give encouragement to trained personal talent. A timely control of setting up mining industry has to be made to avoid extra expenditures to incur on setting up of mining Industry at a delayed time.*

Minerals are the basis of entire economic process, all the great civilisation have developed in and around these resources. The history has taught us this lesson in terms of import budget, which is escalating every year. Therefore we, who are engaged in this process i.e. the development of mineral resources, have great part to play for development of society's future. Minerals have great importance on balance of payments if its development is not taken in hand and developed at an appropriate time, and projects are delayed in just assessing its feasibility and acquiring different approvals, then the escalation of prices and inflation rates may bring us to a degree of no return or shall throw us back many a years. The example is before us when with the blessing of God the steel mill of Kalabagh project 1950 was initiated with initial cost of 154 crores and now it is quite obvious that the cost may exceed at least ten times.

Pakistan has immense mineral wealth which requires speedy development after assessing its quality and quantity. Society should give due encouragement both to professional, trained national talent and the resources so that we should march ahead with the discovery and utilization of the hidden unexploited wealth of Pakistan.

It is discouraging to note that the Nokundi Iron Ore was discovered more than a decade ago and is still in its making up and thus the country has to import a foreign ore for the steel mill at Karachi.

Copper of Saindak Ore has also exceeded its time which needs to be given a due attention both by the authorities and the professionals to be given important wealth of our society as society needs this wealth at an appropriate price. Zinc and lead in Khuzdar should not make its headway towards delay otherwise this will also follow the fate of Kalabagh Steel Mill.

Mineral development is not only a simple process, affecting the industries and exploitation of mannual labour (depending upon the utilization of skilled and unskilled labour) and economics of the country's minerals economically exploited as the ores. Ore creates mining industry, mining industry forms a basis of industrial development that earns foreign exchange. This chain may also serve as a solution of employing the unemployed labour which is a prevalent cause of many problems in the country.

Similarly, it is quite obvious that time is not far away when atomic energy shall replace coal and oil as there is strong energy crisis due to high ever-shooting prices of petroleum. As our country is a poor country and we, importing the petroleum worth to the tune of fifteen billion rupees, cannot aford this luxury. This is a challenge for Geoscientists to find out an alternate to save this hard earned foreign exchange, which we are simply spending in burning the fuel in the air. If we are successful in finding out the alternate such as if we succeeded in discovering the uranium or hidden petroleum wealth, we can save our well earned foreign exchange which can be very properly utilized for installing the different industries based on mineral resources because this is the age of competition and survival. Only those nations will survive and exist in this competitive world who are fittest. As God has already said in the Holy Quran that only those nations will survive and exist who work properly and make efforts for the betterment of their existence. Otherwise they will be subjugated by others (Al Quran).

As I have already indicated that the process is a chain process linking one chain with the other, thus opening the door for the job finding for the new comer from the universities, academics and from almamaters.

If this process in hampered it will further open the avenues for the trained persons to go abroad and finding the jobs and building the empire of other nation, with their services in terms of foreign exchange. This will obstruct and delay country's development. Their services can be best utilized at development projects which is dire need of our Islamic society.

If this field is not given a proper importance in terms of the priorities of society there is every possibility of active physical conflict which may give a set back- that is if human needs are not provided for within a basic economic structure active physical conflict shall break to disrupt the most carefully laid social plans.

Make no mistake. Society must improve the standard of living throughout Pakistan of which the society itself is a part and make priorities in terms of resources in hand and its speedy utilization for the betterment of our country and for the coming generation to serve with love and I shall say in the end again when your survival depends upon mineral resources, its development is never a luxury.

GEOCHEMICAL PROSPECTING AND ITS APPLICATION IN PAKISTAN

BY

LAL BUKHSH BOZDAR

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Abstract : *Geochemical prospecting and its application in Pakistan is described in two parts. The first part reviews development in geochemical prospecting, various geochemical prospecting methods, use of statistics in geochemical data interpretation.*

The second part deals with geochemical propesecting in Pakistan, its importance, need for carrying out geochemical surveys in Pakistan, to outline the geochemical provinces which may ultimately be used with further geochemical investigation, to pinpoint the mineral potential areas, and suggestions for geochemical work.

DEVELOPMENT, METHODS, AND USE OF STATISTICS IN INTERPRETATION OF GEOCHEMICAL DATA

Geochemical prospecting is the practical application of geochemical and biological principles and data in the search for mineral deposits and accumulations of hydrocarbons. The geochemical methods for mineral exploration prove to be most successful when applied with geological and physical exploration techniques.

Following factors have played very important role in the rapid development of geochemical prospecting methods.

1. Recognition of the nature of primary and secondary dispersion halos and trains that are associated with all mineral deposits. These may be :

   (a) Primary dispersion halos in the wall-rocks.

   (b) Primary 'Leakage' dispersion related to blind deposits.

   (c) Secondary geochemical halos in soils overlying sub-outcropping deposits.

   (d) Secondary geochemical dispersion 'train' in the drainage system.

(a) Primary dispersion halos in the wall-rocks

During mineralization diagnostic trace elements may be deposited from hydrothermal solutions impregnating the wall-rocks enclosing the main site of mineralization. Systematic geochemical rock analysis, may, therefore, be useful (a) in increasing the target for ore search by disclosing evidence of chemical alteration that is not associated with visible mineralogical alteration or (b) narrowing down the search by localising the more favourable points for further exploration in areas where wall-rock alteration is widespread.

(b) Primary 'Leakage' dispersion related to blind deposits

Metals may be deposited as visible disseminations along essentially barren fissures followed by the migrating ore-forming solutions. Trace metal deposition making the outlet channels used by residual solutions passing away from main site of ore deposition are referred to as 'Leakage' dispersions, the detection of which give clue to the presence of significant mineralization at depth.

(c) Secondary geochemical halos in soils overlying suboutcropping* deposits

Providing the overburden is residual in origin, abnormal concentration of trace elements almost invariably occur in soil overlying the suboutcropping deposit. Several factors, such as topography, soil type, pH and nature of the bedrock have modifying influence on the size and form of the anomalies. The process where by the metals are introduced into the overburden are considered to include :

(i) mechanical incorporation.

(ii) migration in ground water solutions, metals leached from the underground deposits.

(iii) extraction of metals by deep-rooted vegetation followed by their return to surface soil through decomposition of the plant material.

(d) Secondary geochemical dispersion 'train' in the drainage system

1. A major portion of the product of whethering and erosion are funnelled down the drainage system, and it is, therefore, possible at times to discriminate between barren and mineralized catchment areas by determining the trace metal content of the stream waters and the active stream sediments.

2. Development of accurate and rapid analytical techniques utilizing the spectrograph, and various specific sensitive colorimetric reagents especially dithizone (diphenylthiocarbozone) for estimating the amounts of various metals in substances.

3. Development of resins and polythene laboratory ware of all types which reduce the incidence of contamination.

4. Development of Atomic Absorpotion Spectroscopy.

This method was developed by A. Walsh in Australia. Because of its speed, sensitivity, and relative freedom from interferences, the method permits the rapid analysis of rocks, soils, waters and biological materials in both field and established laboratories for a great varieties of elements present at low concentrations.

5. Development of Gas Chromatography.

This is the most significant development regarding the rapid analysis of traces of hydrocarbon in petroleum prospecting using rocks, soils and water. The method permits the determination of various hydrocarbons in parts per billion.

GEOCHEMICAL PROSPECTING METHODS

These methods using different types of materials are as under :

(i) Lithogeochemical methods

These methods are based mainly on the analysis of rocks for outlining the geochemical provinces.

(ii) Pedogeochemical methods

These methods are based on the analysis of soil, till and other geochemical material and help in outling the belts or zones containing mineral deposits or hydrocarbons.

In general 'B' horizon of the soil has been used extensively for survey, but deep drilling and sampling near bed-rock has been employed in many areas of transported over-burden.

* In geochemical prospecting a geologic feature is said to be suboutcropping when it intersects the surface of bed rock but concealed by residual or transported overburden.

(iii) Hydrogeochemical methods

These methods are based on analyses of natural waters and their precipitates and on stream sediments. These methods have proved invaluable in localising mineral belts in many parts of the world under a variety of conditions.

(iv) Biogeochemical methods

The trace element of trees and others vegetation is used in outlining secondary dispersion 'halos' in soil and over-burden. The use of toxic effect of an over abundance of trace elements in soils which can cause visible physiological effects in vegetation or diminish or inhibit the growth of various species of plants is also helpful. Still another method uses the fact that certain plants known as indicator plants grow in zones where trace elements such as zinc, copper etc. are present in super abundance. Other biogeochemical methods are based on the fact that bacteria and other organisms grow profuesly where hydrocarbons and other substances are concentrated in rocks, soils or overburden.

(v) Atmogeochemical methods

These methods in strict sense utilize gases as the medium of analysis. More generally they compromise analyses of more volatile of the elements in nature such as mercury, arsenic, antimony, iodine etc. Since the natural gases and more volatile elements and compounds in nature migrate to considerable distances from their focus of accumulation, the halos which they produce are generally broad and extensive. Survey based on the dispersion of mercury are good for locating deeply buried types of sulphide deposits (Lead-Zinc and Silver).

Radon (Rn-222) has been effectively used in geochemical prospecting for uranium deposits utilizing soils.

Oxidising sulphide ores under certain conditions give off sulphur dioxide, that in fact can be often detected simply by its odours from selenium compounds have been reported from areas of seleniferous rocks.

6. Other geochemical methods for mineral deposits

Heavy mineral surveys have long been used in prospecting and in the part led to the discoveries of gold, tin, tungsten, platinum, lead, zinc, silver and other types of deposits. Modern techniques still use panning methods but are followed by detailed mineralogic, spectrographic or other analyses of the elemental constituents of the heavy residues.

Isotopic methods based on the distribution of lead, sulphur and other isotopes may be of interest in geochemical prospecting. Lead isotopic data may be useful in some areas in the search for lead and silver deposits.

Finally man's best friend, the dog has recently been pressed into service to locate mineral deposits by sniffing out boulders of ore occurring in the dispersion trains and fans of sulphide deposits. These living "Scientillometers" can apparently be trained to become quite sensitive to sulphur dioxide and other gases associated with oxidising sulphides and are said to be quite effective.

THE APPLICATION OF STATISTICAL METHODS OF DATA INTERPRETATION

The data of geochemistry are inherently numerical and it is the task of the geochemist to relate these data to features of environment from which the sample analysed were drawn. This task is not simple as samples are mixture of material from a number of sources.

For a particular element or compound each of the environment is characterised by a population of data having a discrete mean and variance. The task of interpretation is either to isolate data drawn from a certain population associated solely with an economic concentration of some minerals or to isolate data drawn from a larger population of which only part is related to an economic mineral concentration.

Histograms and cumulative frequency plots were and are still used in the first stage of interpretation to determine if the data are multimodal or unimodal and of aid in the selection of contour intervals for plotting of single element geochemical maps.

These same histograms and cumulative frequency plots also lead at a very early stage to the recognition that in many cases the data are log normally distributed.

The methods of statistical analysis may be divided into two group (i) Univariate methods which are applicable to single element or radical and (ii) Multivariate methods which are applicable to two or more elements or radicals.

Before the application of any statistical analysis techniques, the data should be checked for sampling and analysis errors.

The univariate forms of data of analysis fall into two groups : firstly, methods which investigate the areal distribution of data and secondly, those methods which investigate the data from the view point of casual influences on the observed population.

The areal distribution of data may be studied by moving average technique called Rolling Mean or Surface filling techniques based on least square fits of mathematical functions. The two most common functions are the Fourier and Polynomial.

Multivariate statistical is one of the most powerful tools available for processing of data. Three forms of analysis used are (i) Cluster (ii Discriminant analysis and (iii) Factor analysis.

Cluster analysis can be used to group samples or variables together which show either considerable affinity in their element content or in either response to casual stimuli.

Discriminant analysis can be used to test whether data belongs to one of two or more populations. The data must be divided into groups in order to set up the discriminant factor.

Factor analysis is a technique by which the inter-relation within a set of data can be studied and used to divide the data into number of groups. Two modes (Q-mode and R-mode) of factor analysis have been used in the interpretation of exploration geochemical data—The Q-mode which studies the inter-relation between samples and attempts to establish a set of end members by which data variability may be described, and R-mode in which the inter-correlations of the variables are studied and used to establish a new set of parameters with which to describe the data variability.

GEOCHEMICAL PROSPECTING IN PAKISTAN

Introduction

Pakistan is a developing country and its economy is mainly agriculture based. During the past many years Pakistan has been trying to move towards Industrial side and 'Pakistan Steel' is one of the major steps forward in this direction.

Better agriculture produce and improved food grain productivity depends on seeds of High Yield Varieties (HYV), chemical fertilizers, and pesticides. Manufacture of fertilizers, and pesticides, heavy and light industries need minerals as 'raw material' for their productions. Some of the non-fuel minerals required as raw materials are so important that they may be called 'Strategic Minerals'. Therefore, it is very imperative for our survival that the mineral wealth of our country should be tapped on priority basis.

In Pakistan mineral prospecting has largely been confined to areas of outcrop in mineralized parts, and most discoveries of minerals have resulted where their surface expressions were visible which may be called as "Visual Prospecting". This visual phase of mineral prospecting is rapidly passing out and it is need of the time that different government agencies and corporations involved in mineral prospecting should concentrate on the discovery of hidden ore deposits and accumulation of hydrocarbons.

U.S.S.R. and Scandinavian countries are the main contributors, U.S.A., Canada, Great Britain and many other countries have used these methods extensively in mineral and petroleum exploration both by mining and government agencies.

Different government agencies and corporations of our country involved in mineral prospecting have not much involved themselves in geochemical prospecting methods, whereas the geochemical methods can be based on any of the materials of the five spheres of the earth viz Lithosphere (rocks), Pedosphere (Soil, till and other surficial material), Hydrosphere (natural waters), Atmosphere (gases) and Biosphere (living organisms and their fossil equivalents).

Importance

Favourable environments for new mineral occurrence in our country cannot be recognised without a sound appreciation of the detailed geology of mineral environment and its orientation in the sequence and location of geological events of the region.

For the discovery of new minerals the geological knowledge of our country should be increased and expanded and efforts should be continued in the interpretation of the complex geological events which create mineral deposits.

Geochemical prospecting used in conjunction with the knowledge of the above factors would help in finding out the areas where possible mineralization may have occurred and the limit of the area could be still narrowed down by the detailed geochemical investigations.

Geochemical prospecting methods is the only direct approach to the problem of minerals, oil and natural gas exploration, whereas the geophysical methods will always remain indirect since they are based on secondary or induced properties of the elements or their minerals.

Geochemical prospecting is relatively cheap. The low cost arises not only from the rate at which ground can be covered and the simplicity of the capital equipment required, but also from the fact that the entire routine of sampling and analysis can safely be undertaken by non-qualified personnel. There are, however three mandatory pre-requisites for effective operations, namely (i) that the routine procedures should be established by a competent orientation survey in each new area. (ii) that the routine operatives should be properly trained and organised and (iii) that the survey should be controlled and the data interpreted by one who is experienced in geochemical techniques. Number of samples to be collected, area to be covered, number of elements to be determined on each sample and the depth at which the samples shall be taken help in estimating the cost of analysis.

The cost of geochemical analysis can essentially be reduced if large scale operations are taken in hand.

OUTLINING GEOCHEMICAL PROVINCES

The important factor in geological prospecting is to outline the geological provinces or the areas whose country rocks contain higher than normal amounts of particular elements. The general thought behind this type of work is that these geochemical provinces may contain concentrations of the particular elements or hydrocarbons. The geochemical provinces are outlined by carrying out the analysis of rocks or particular mineral in rocks (lithogeochemical methods). The detailed local work should be done to outline primary dispersion halos which are associated with most types of mineral deposits and accumulations of hydrocarbons.

The outlining of geochemical provinces mainly depends on the frequency of the rock outcrop and type of deposits in the terrane. To be effective, rock types must be distinguished and geochemical maps for each of the rock type must be prepared.

It has become apparent that geochemical provinces are important in geochemical prospecting. Therefore, the first step towards the geochemical prospecting in our country would be to outline the geochemical provinces and carry out detailed work for dispersion halos.

Once the geochemical provinces are outlined then the geochemical methods described in the paper should be used for detailed chemical analysis to establish dispersion halos which will help in narrowing down the limits of the expected mineralized area and ultimately may lead to the discovery of the hidden ore deposits.

POSSIBLE GEOCHEMICAL PROVINCES OF PAKISTAN

(1) Areas with granitic instrusions.

(2) Areas with basic intrusions.

(3) Sedimentary environments (carbonate rocks and balck shales).

1. Areas with Granitic Intrusions

If an area with granitic instrusives exceeds in the normal content of tin, tungsten, molybdenum, copper, then this area may have associated tin, tungstan, molybdenum and copper deposits. Granitic and gnessic terranes are relatively high in uranium.

2. Areas with Basic Intrusions

Areas of basic intrusives and having higher than average content of nickel, copper, platinum, vandium and titanium may have associated nickel, copper, platinum, chromium, vanadium and titanium deposits.

Evidence for a high sulphur content in mafic and ultra-mafic rocks is an important factor in the appraisal of mafic rock bodies as a source of nickel sulphide minerals. Where sulphur content and pressure in the rock magma is sufficiently high a large part of nickel may crystallise and concentrate in sulphide minerals instead of silicate minerals. This is an important environmental factor in rendering nickel recoverable as a sulphid mineral. An important guiding factor, therefore, in exploration is to concentrate work on mafic and ultramafic rocks that have evidence of high sulphur centent.

3. Sedimentary Environments (Carbonate Rocks and Black Shales)

Increasing attention should be paid to sedimentary environments for black shales and carbonate rocks as these are the important domains for copper, uranium, vanadium, lead, zinc, silver and host of other minerals.

Carbonate rocks with abnormal amounts of lead-zinc-silver may contain Lead-Zinc-Silver deposits.

SUGGESTIONS

Pakistan is a very potential area for tapping its mineral wealth but her present mineral position is not satisfactory. She lags far behind internationally in mineral reserves and production. Mineral and Fuel sector of Pakistan hardly contributes only 1.0% of gross national product. The recognition of its favourable areas for prospecting and appraisal of mineral potential will obviously be based on comprehensive knowledge of geological environment necessary for different types of mineral occurrences followed by geochemical prospecting techniques.

The potential value of geochemical prospecting in our country also lies (i) in the rapid reconnaissance of comparatively large areas by rock, soil and stream sediment sample analysis. (ii) Recognition of Primary and secondary dispersion patterns which in turn will help in finding the hidden ores.

The geochemical surveys in following areas should be taken on priority bases.

(i) Nagar Parkar (Sind) and parts of N.W.F.P. and Baluchistan dominated by igneous intrusion.

(ii) All those areas throughout the country where mineral showings (minor occurrences) have been reported.

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THE STUDY OF GLOBAL CLIMATES OF THE GEOLOGICAL PAST—A MICROPALEONTOLOGICAL APPROACH

BY

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INTRODUCTION

Major climatic events in the geologic past have left a variety of retrievable records in the sediments, both on land and sea. Some marked fluctuations in the climates are evident from widely distributed sedimentological, geochemical and paleontological features. Here we are mainly concerned with the paleontological record of widespread latitudinal domination of certain floral and faunal elements during times of extreme climatic change. Numerous intervals during which paleobiogeoraphic patterns show poleward extension of tropical assemblages, or equatorward extension of cold, higher latitude assemblages, have been documented for the Cenozoic. These events were formally termed as climatic *acme events* (indicating peak climatic change) by the author (Haq, 1980) and have been used successfully in the reconstruction of the global paleoclimate. The purpose of this paper is to describe and illustrate the concept of climatic acme events with examoles from the Cenozoic marine and terrestrial record, and where available, evidence from the oxygen-isotope record that corroborates the paleontological conclusions.

The concept of acme events was informally introduced by Haq and Lohmann (1976). The maxima of migrationary cycles were termed "acme horizons", and defined as the levels in relatively continuous sequences characterized by the maximum abundance of and environmentally sensitive assemblage. If one assumes that times of extreme environmental (climatic, oceanographic) change are, geologically speaking, contemporaneous over large geographic areas, then the acme events will define time-equivalent horizons. The precision with which acme horizons approximate synchoronous surfaces depends on our ability to unambiguously identify the acme events (maximum geographic shifts of assemblages). This is affected both by the complexity of the migrationary cycles and by resolution of the method used to delineate them.

The recognition of acme events involves the use of paleobiogeography data (distribution of organisms in space and time) to delineate the cycles of latitudinal migrations of assemblages in stratigraphic sequences over wide geographic areas. The method involves the following steps :—

(1) data census of a particular fossil group from relatively continuous sequences in sediment samples in which the fossils are relatively well preserved, (2) standardization and reduction of data with the help of an appropriate quantitative analytical technique, which reduces the raw census data into few "factors" (assemblages) that explain a large share of the variance in the data matrix, and (3) delineation of the distribution patterns of the quantitatively defined assemblages on a time-space grid and recognition of individual migrationary events.

CENOZOIC EXAMPLES

In a series of recent studies the Cenozoic biogeography of calcareous plankton (nannoplankton and planktonic foraminifera) has been delineated for the Atlantic Ocean. Numerous latitudinal migrations of assemblages have been recognized in both the Paleogene and the Miocene. Examples of some of the more prominent acme events are included below and the results are compared to oxygen-isotopic data, where available.

Figure 1 shows the nannofloral and planktonic foraminiferal migrationary patterns recognized by Haq and others (1977) in the North Atlantic Paleogene (65 to 25 Ma). The most prominent acme events that are evident from both the nannofossil and the foraminiferal migrationary patterns are described below :

1. The middle Paleocene (60—57 Ma) shift of both high latitude nannofloral and foraminiferal assemblages to low latitudes in response to a marked cooling at this time.
2. A latest Paleocene-early Eocene (53-49 Ma) shift of low latitude nannofloral assemblages to high latitude and withdrawal of the latitude assemblages, combined with a maximum incrusion of low-latitude foraminiferal assemblage to mid latitude as well as the mid-latitude assemblage to higher latitude, as a result of a peak warming at this time.
3. A middle Eocene (46-44 Ma) incursion of higher latitude assemblages into lower latitudes in response to a cooling, when high-latitude nannofossil assemblages once again return to temperate and tropical areas and the high-latitude foraminiferal assemblage makes its first prominent appearance in mid latitudes.
4. A second incursion of a globigerinid assemblage into middle and lower latitudes in the late Eocene-early Oligocene (38-36 Ma) indicating a marked cooling at this time.
5. A third incursion of the high-latitude globigerinid assemblage into lower latitude occurs in the middle Oligocene (32-31 Ma). This cooling event is also indicated by the migration of high-latitude nanno-assemblages into low latitudes at this time. This acme event seems to have been at least equal in intensity to the latest Eocene-early Oligocene event of marked climatic deterioration between 38 and 35 Ma.

Supporting evidence for most of these paleoclimatic conclusions based on calcareous plankton acme events comes from other independent criteria. On land, the early Eocene acme event, indicating peak-warming, manifests itself in a major expansion of tropical/subtropical land plants as far as 40-45°N latitude (Wolfe, 1978) on the west coast of North America, and subtropical floral elements are found as far north as 60°N in the early Eocene in the Gulf of Alaska borderlands area, based on a revised age estimate (Wolfe and Poore, 1980). In general, land plants indicate significantly higher mean annual temperatures in the Northern Hemisphere and low latitudinal temperature gradients in the early Eocene (Wolfe, 1978).

The evidence from land plants also corroborates the latest Eocene cooling episode, when the flora indicates that the mean annual temperature on land were lowered significantly and at the same time mean annual range of temperature increased drammatically (Wolfe, 1978), supporting the marked climatic deterioration scenario.

In recent years the analyses of stable isotopic ratios of oxygen and carbon in marine calcareous microplankton and benthos have become powerful tools for paleo-environmental interpretation. An analysis of oxygen isotopes in well-preserved calcareous micro-fossils from a deep-sea core sample can yield information about such paleoceanographic variables as the surface water temperature through the analysis of shallow-dwelling planktonic foraminifera : bottom water temperature through analysis of benthic foraminifera : and the structure of the thermocline through analysis of deeper dwelling planktonic species. In addition, interprerations of former bottom water temperatures in the deep ocean are also indicative of surface water temperatures that prevailed at higher latitudes where cool, denser water sinks to form bottom water. Thus a comparison of planktonic and benthic isotopic temperatures also yields information about the past latitudinal thermal gradients.

Oxygen-isotopic data from various parts of the ocean also lend support to the marked climatic changes and spatial migrations (See Figure 2). A decrease in benthic isotopic temperature in the middle Paleocene has been documented from South Atlantic DSDP site 357 on the Rio Grande Rise and from western North Atlantic site 384. At the latter site the plantonic foraminiferal data also show low isotopic temperature in the middle Paleocene between 61 and 60 Ma. Buchardt (1978) recorded a similar low temperature value based on oxygen isotope analysis of mollusc shells from NW Europe and the North Sea.

The latest Paleocene-early Eocene climatic amelioration has been documented in numerous oxygen-isotopic studies (Figure 2). High isotopic temperatures based on both planktonic and benthic foraminifera were recorded in southern high latitude site 277 on Compbell Plateau (S.W. Pacific Ocean) the temperatures were highest recorded in the entire late Paleocene to Recent stratigraphic interval. The molluscan oxygen isotopic curve also shows a sharp rise in paleotemperature of shallow marginal seas in NW Europe in the late Paleocene-early Eocene. Similar trends of isotopic temperature elevation have also been recorded in the late Paleocene-early Eocene sequences at sites 398 and 401 in the North Atlantic in both the benthic and planktonic foraminifera.

All the data cited above bears upon the conclusion that the latest Paleocene-early Eocene represents the warmest period of the entire Cenozoic in the marine realm. On land mean annual temperatures were also considerably higher than at the present time (Wolfe, 1978). This peak climatic amelioration also seems to have triggered higher evolutionary turnover in phytoplankton and foraminifera, when both nannoplankton and planktonic foraminifera show high evolutionary rates culminating in a peak in pelagic diversity in the middle Eocene (Haq, 1973).

Figure 3 summarizes the nannofloral migrations in the North Atlantic in response to climatic acmes during the Miocene. Most of the biogeographic "activity" is confined to the mid to high latitudes which show the most distinct migrationary patterns. This record shows four cooling events, alternating with four warming events of varying intensity and duration. Earliest Miocene is generally cooler, when little or no biogeographic activity is observed and a stress-adapted, cosmopolitan assemblage dominates most latitudes. First warm acme occurs between 22 and 20 Ma, with a peak at about 21 Ma. The second warming event occurs between 17 and 15 Ma when mid latitude nannofloras expand into higher latitudes. This is followed by a generally cooler interval up to 12.5 Ma, to be followed by a second incursion of mid latitude nannofloral element into higher latitudes indicating a warming between 12.5 and 11.5 Ma with peak around 12 Ma. The third expansion of mid latitude assemblage into higher latitudes occurs between 9 and 7.5 Ma with a peak around 8 Ma. The late Miocene interval, after this last warming, is characterized by cool climates

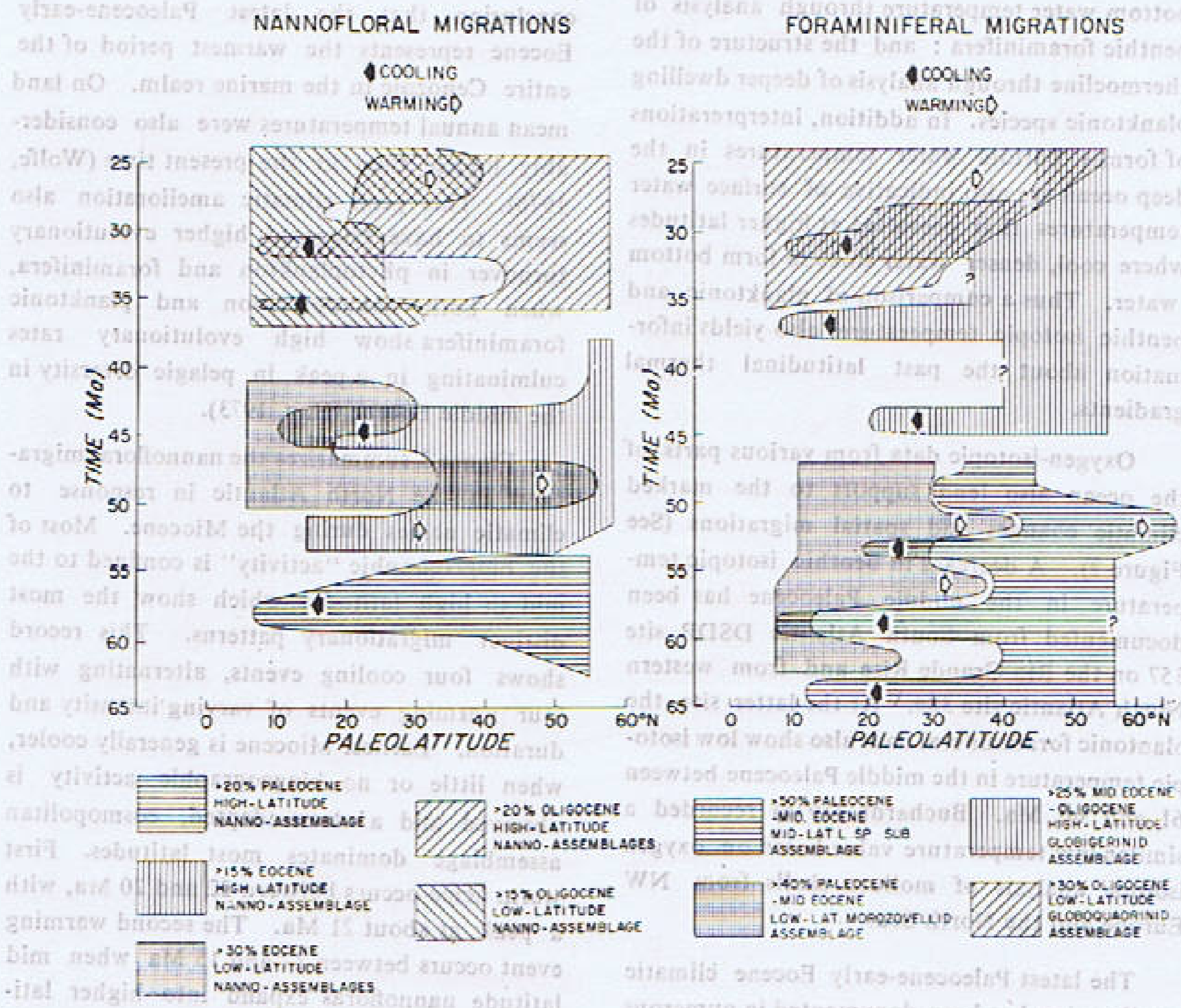

Fig. 1. A summary of the major nannofloral and foraminiferal migrationary patterns in the North Atlantic Ocean through the Early Cenozoic. Migrations towards higher latitudes are interpreted as being caused by climatic warming and towards lower latitudes by climatic cooling. The patterns delineated enclose all samples which contain abundance greater than those indicated in the legend. Arrows in these areas indicate the direction of the major shifts of assemblages. Major and minor nannofloral assemblages with similar latitudinal preferences have been combined to obtain composite patterns in some cases. (From Haq and others, 1977).

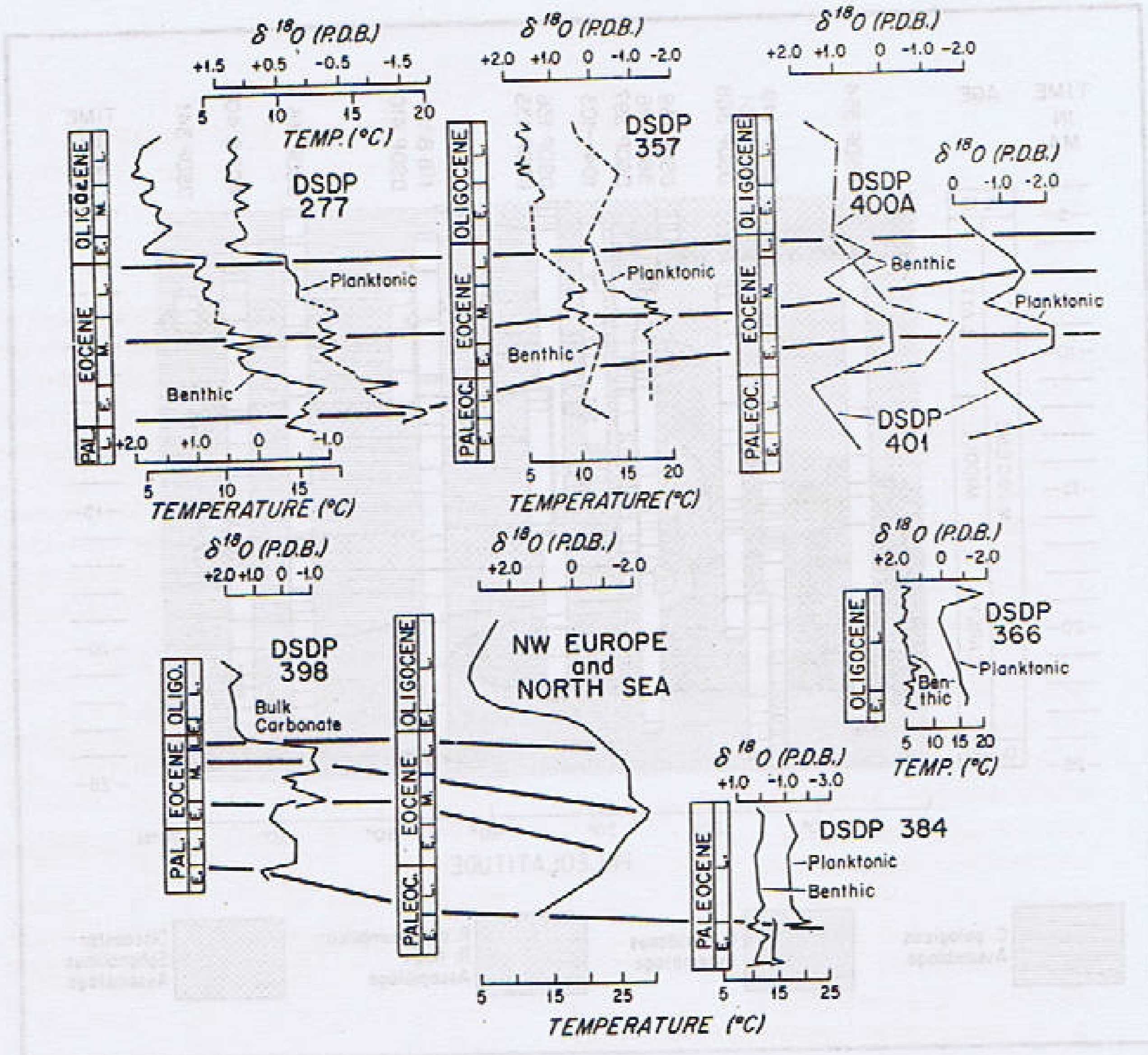

Fig. 2. Paleogene oxygen isotope stratigraphy of D S.D P. sites from published sources. Planktonic and benthic foraminiferal δ 18O curves from Site 277 after Shackleton and Kennett (1975); Site 357 after Boersma and Shackleton (1977); Sites 398, 400 and 401 after Vergnaud-Grazzini (1978); generalized mollusc δ 18O curve from N.W. Europe after Buchardt (1978); planktonic and benthic foraminiferal curves from Paleocene of site 384 after Boersma and others (1979); and Oligocene planktonic and benthic curves from Site 366 after Boersma and Shackleton (1978) Lines are drawn through the climatic acme events that have been identified through calcareous plankton migrationary patterns (Haq and others, 1977).

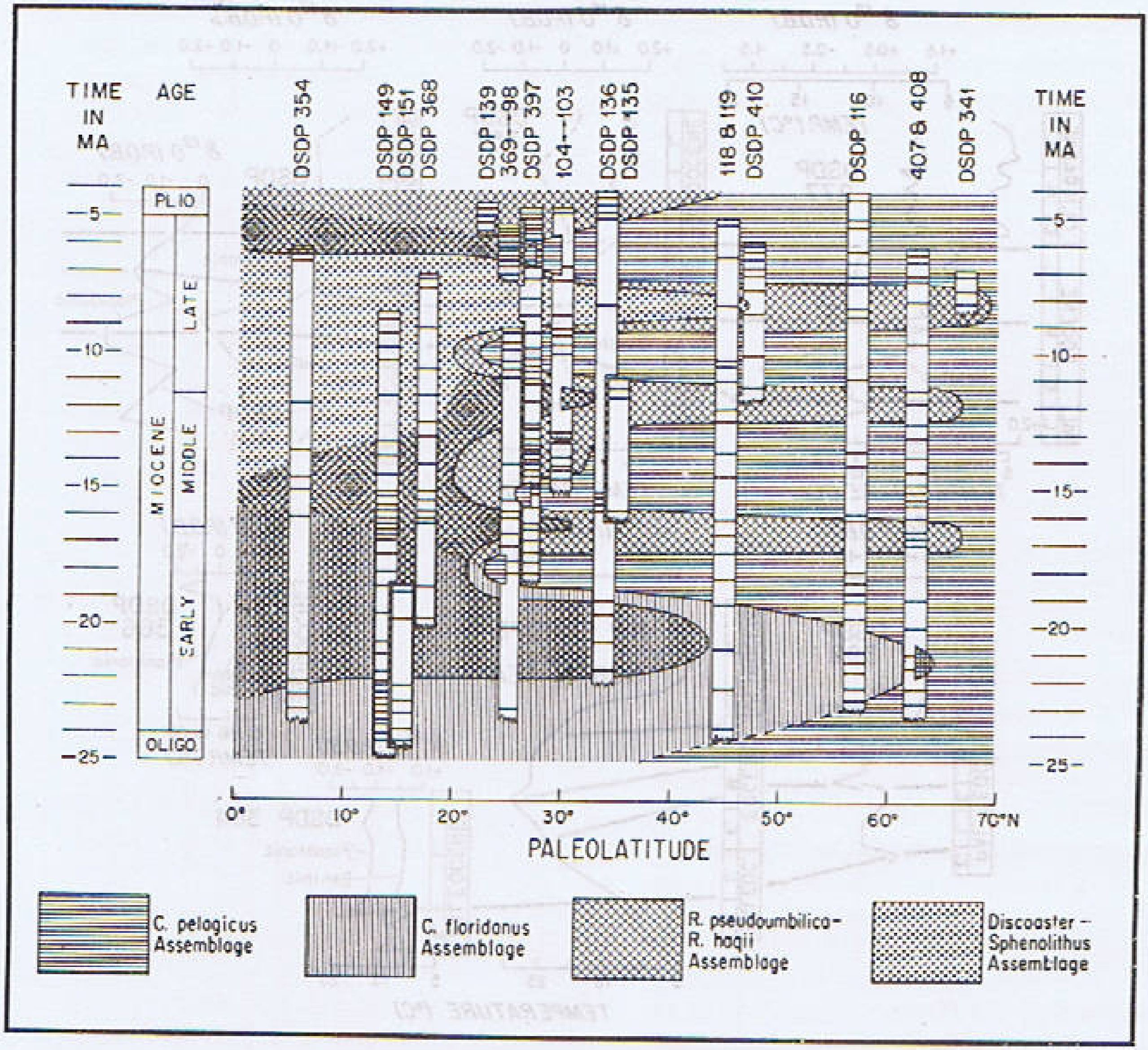

Fig. 3. A summary of nannofloral migrationary patterns in the North Atlantic Ocean through the Miocene. D.S.D.P. cores are represented by the appropriate site number and sample levels in these cores are represented by lines. Miocene record shows four climatic warming episodes as indicated by low and mid latitude assemblage incursions into higher latitudes, and four cooling episodes and indicated by expansion of *C. pelagicus* (high latitude) assemblage into lower latitudes. (From Haq, 1980).

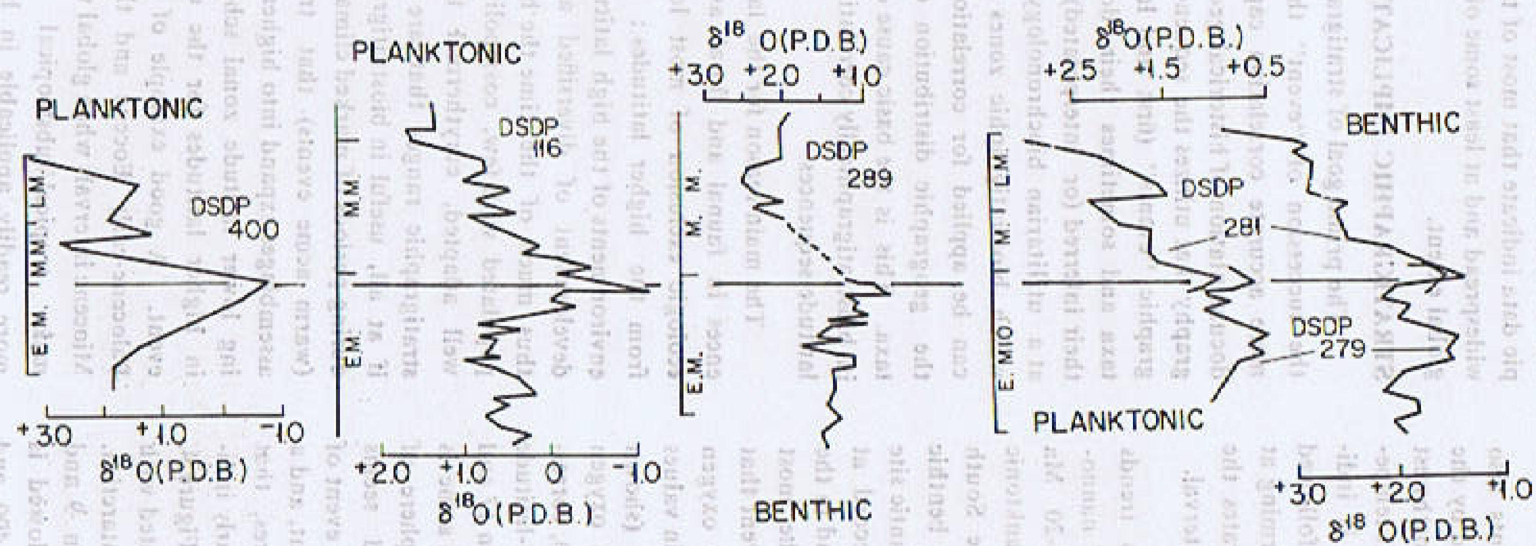

Fig. 4. Miocene oxgen isotope stratigraphy of D.S.D.P. sites from various sources: Planktonic foraminiferal curve from D.S.D.P. site 400 after Vergnaud-Grazzini and others (1978) and site 116 vide Rabussier-Lointier and others Vergnaud-Grazzini, written communication, 1980); benthic foraminiferal curve from D.S.D.P. Site 289 vide Woodruff and others (Woodruff, written communication, 1980) and planktonic and benthic foraminiferal curves from D.S.D.P. sites 279 and 281 after Shackleton and Kennett (1975). The line is drawn through the major warm climatic acme between 17 and 16 Ma (see text).

and high latitude nannofloral elements are found as far south as 25°N.

Some of these Miocene acme events also manifest themselves on land as indicated by the terrestrial plant record from Pacific Northwest and Alaska (Wolfe and Poore, 1980). At temperature elevation in the middle Miocene is indicated between 17 and 15 Ma, which is followed by a cooling, and then a renewed warming at 8 Ma. Terrestrial record also corroborates the latest Miocene to be a generally cool interval.

The oxygen isotopic record shows trends that are in general agreement with the nannofloral record (see Figure 4). The 22-20 Ma warming trend can be observed in planktonic and benthic isotopic record from the South Pacific, high latitude site 279, from the benthic and planktonic record at North Atlantic site 279, from the benthic and planktonic record at North Atlantic sites 398 and 116, and in the record at South Atlantic site 357. The most obvious and the warmest Miocene event that has been documented in most Miocene oxygen isotopic curves is the marked decrease in values at the early-middle Miocene boundary (shown by a line through the peaks in various oxygen isotope curves reproduced in Figure 4), corresponding to the first incursion of mid-latitude assemblages into high latitudes between 17 and 16 Ma (see Figure 3). This nannofloral acme is also observed in the Southern Hemisphere of the Atlantic Ocean (Haq, 1980) and seems to have been the most marked climatic event of the Miocene epoch. The cooling event, and a relatively sharp drop in temperatures, that followed this warm episode is also clearly indicated by isotopic curves reproduced in Figure 4. This cold acme seems to have been related with the onset of extensive glaciation on Antarctica. The late Miocene warming between 9 and 7.5 Ma and the cooling event that followed is also evident from the curves for sites 400 and 281 (Figure 4).

These examples from the Cenozonic acmes and corroborative evidence from oxygen isotopic data indicate that most of these events were widespread and at least some of them were of global extent.

STRATIGRAPHIC IMPLICATIONS

The prime goal of stratigraphy is to order the succession of "event" that lead to ever more accurate correlation capability for the documentation of historical geology. Biostratigraphy that utilizes the sequences of biostratigraphic "events" (first and last occurances of taxa and sometimes their dominances) and their inferred (or interpolated) ages to arrive at a utilitarian biochronology. The extent to which biostratigraphic zones or datum-events can be applied for correlations is limited by the geographic distribution of the defining taxa. This is the basic cause of the difficulties in biostratigraphically correlating high and low latitude sequences.

The main reason for the latitudinal differences in faunal and floral assemblages is the ecologic exclusion of most low latitude taxa from the higher latitudes ; the high-stress environments of the high latitudes inhibit the development of diversified assemblages and thus much of the time the high latitudes are populated with few, cosmpolitan, robust and well adapted, eurythermal taxa, with long stratigraphic ranges that are only marginally, if at all, useful in biostratigraphy. It is only during periods of marked climatic ameliorations (warm acme events) that tropical/temperate assemblages expand into higher latitudes, making lower latitude zonal schemes applicable in higher latitudes for the duration of the event. A good example of this is the late Palocene-early Eocene and the early middle Miocene intervals when global warming episodes make tropical/substropical biostratigrapies more readily applicable in higher latitudes. During other times in the Cenozoic the low and high latitude correlations are difficult at best.

The delineation of migrationary patterns of assemblages in response to climatic acmes can provide a solution to the high to low latitude correlation dilemma. As mentioned earlier, if the times of extreme environmental changes are geologically contemporaneous, then acme events will approximate synchronous horizons. Acme horizons or maxima in migrationary cycles, will define approximate time lines, and both the warm and cold acme events can be conveniently used for correlation purposes.

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AN IMPROVED METHOD FOR PRECISE DETERMINATION OF FERROUS IRON IN NONREFRACTORY SILICATE ROCKS AND MINERALS

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Abstract : *The FeO content of 100 mg samples of silicate rocks is determined by this method. The sample is decomposed with hydrofluoric acid and sulfuric acid by heating for two minutes at a temperature of 270 ±10 C°. The decomposed sample contained in a covered platinum crucible, is transferred, with its lid, to a beaker containing reducing solution of boric acid alongwith 2.5 ml conc. phosphoric acid and few drops of indicator (0.2% sodium diphenylamine sulfonate). The content of the beaker (with completely immersed crucible) is carefully mixed and titrated against N/100 $K_2Cr_2O_7$ solution. Determinations of FeO content by this simple and rapid method, using new values for optimum heating time and temperature, were made in nine different "French Geochemical Standards. The FeO values are in excellent agreement with those recommended from results obtained by various laboratories by different lengthy and complicated methods. The total time required, by the present method, for each determination of ferrous iron does not exceed five minutes.*

INTRODUCTION

Iron exists in ferrous, ferric and (rarely) metallic forms in the geological materials. The valence state (s) in which it occurs, is a matter of great importance in geology. Unfortunately the methods for determining ferrous iron, are still not reliable.

Mineralogists and petrographers attach great importance to the ferric/ferrous iron and regard it a very useful parameter to understand chemical equilibrium in rocks and their femic mineral compositions as well as prevailing oxidation conditions. Therefore, precise ferrous iron determinations are essential. Ferrous iron is usually the simplest and quickest determination in silicate analysis, however, its precise determination is complicated by air oxidation. This menace has spurred scientists to develop better methods for the deterimination of ferrous iron. The fundamental requirement of any such method involves the complete decomposition of the sample and the perfect protection of the liberated ferrous iron from air oxidation.

There are quite a number of methods already available for the estimation of ferrous iron in silicate rocks. Hey (1941) developed a technique which involved fusion of refractory silicate minerals with sodium metafluoborate and used iodine monchloride solution in hydrochloric acid for the estimation of ferrous iron, the liberated iodine being titrated with potassium iodate. Methods are available, which have been reported even earlier, by Guthrie and Miller (1933), Hecht (1937), Shioiri and Mitui (1938). Similarly Das Gupta (1941), Vincent and Philips (1954) tried to develop some improved versions of already existing macroprocedures for the determination of ferrous iron in silicate rocks and minerals. Groves (1951), Hillibrand *et al.* (1953), Furman (1966), Maxwell (1968) and Bennett *et al.* (1971) published methods, most of which are modified forms of Pratt's method and involved either visual or potentiometric titration for the estimation of ferrous iron ; colorimetric methods have also been included.

During the past few years some of the scientists like Jackson (1957), Riley (1958), Gekht and Putok (1960), and Wilson (19ℓ0), and Wilsom (19ᶦ0) developed methods which involve the decomposition of silicate rocks and minerals in the presence of excess of oxidant. Meyrowitz (1963) developed a method which involves sample decomposition, in the absence of an oxidant, by heating sample with hydrofluoric acid and sulphuric acid,the decomposition mixture is added to an excess of potassium dichromate. The ferrous iron is determined by back titration of the unused dichromate. Clemency and Hanger (1961) determined ferric iron before and after oxidation and calculated ferrous iron by difference. Some other scientists like Riley and Walliams (1959), Shapiro (1960), Shapiro and Brannock (1962) and Wilson (1955, 1960) have developed spectrophotometric techniques for the estimation of ferrous iron is silicate rocks and minerals.

The authors have been using Riley's method (1958) and Meyrowitz's method (1963) with satisfaction, regarding the absolute (or nearly absolute) methods. The same methods when applied to "French Geochemical Standards" were found to produce inconsistant results which were considerably lower than the recommended values (Table-1) Similarly Bennett and Leed's method (1971) should not be used because of the difficulty of maintaining of the acid mixture only in the lower portion of the platinum crucible without letting in boil in the upper portion. In order to overcome these difficulties, optimum heating time and temperature were sought and established while evolving an improved version of the above three methods (Riley - 1958, Meyrowitz - 1963 and Bennett and Leed 1971). Similarly optimum quantities of the chemical reagents were fixed.

TABLE 1

Ferrous iron estimations in DR–N with a recommended Fe 0 value=5.42% (Roche and Govindaraju, 1969)

Ferrous Iron Content (%)

No.	Meyrowitz's Method (1963)	Riley's Method (1958)
1	0.68	1.93
2	1.15	2.05
3	0 57	1.98
4	1.03	2.10
5	1.05	1.85
6	1.12	1.95
7	1.09	1.90
8	1.06	2.01
9	1.05	2.03
10	1.10	1.77
11	1.15	2.08
12	1.02	1.82
	Mean=1.20	Mean=1.96

Std. Deviation=±0.1586

Std. Deviation=±0.1054

EXPERIMENTAL WORK

Reagents

1. Hydrofluoric acid (HF) 48% (ACS reagent)
2. Sulfuric acid (H_2SO_4) 25% or 9N ,, ,,
3. O-Phosphoric acid (H_3PO_4) Conc. ,, ,,
4. Boric acid (H_3BO_3) 5% ,, ,,
5. Sodium diphenylamine sulfonate dissolved in water (Indicator). 0.2% ,, ,,
6. Potassium dichromate solution ($K_2Cr_2O_7$) N/100 ,, ,,

The preparation of above reagents (except Boric acid) do not require any explanation. Boric acid is prepared (as suggested by Groves, 1951) by taking one litre of distilled water and fifty grams of Boric acid in a 2 litre flask. Water is boiled until air-free. The flask is then connected with a cylinder of carbon dioxide and cooled under the water tap in an atmosphere of carbon dioxide, and finally stoppered.

Procedure

Weigh 100 mg of silicate rock/mineral powder (100 mesh or finer) into a 25 ml platinum crucible with a well fitting lid and a flat base of 2 cm diameter. A flat base is essential for the complete decomposition of the sample within the 2 minutes period. Moisten the powder with 2-3 drops of water. Transfer 5.5 ml HF, using a plastic pipette and an automatic pipette filler. Stir the powder a little with a three inch-long platinum rod to prevent caking. Wash stirrer immediately with 2.5 ml. of 9N, H_2SO_4 and gently drop a small plastic covered bar magnet already washed and cleaned with 9N, H_2SO_4. Cover the crucible with its lid and place it on magnetic hot plate previously maintained at 270±10C°. At the same time start an automatic timer and continue heating for two minutes. In the meanwhile transfer 50 ml. of 5% H_3BO_3, to a 250 ml beaker alongwith 50 ml. of freshly distilled water, 2.5 ml. of conc. H_3PO_4 and 0.6 ml. of 0.2% indicator. The efficiency of the indicator is reduced to 20% if it is dissolved in the sulfuric acid solution instead of water. Normally 0.6 ml. of the aquous indicator proves to be satisfactory for the detection of the end point; but more than 3 ml. is required if it is dissolved in sulfuric acid. At the conclusion of the heating period, at once grasp the crucible with platinum—shoe tongs, keeping the lid intact, and swiftly submerge it in acid mixture in the beaker. Stir the contents of the crucible well but cautiously without letting the crucible get exposed to air. Titrate immediately with standard $K_2Cr_2O_7$ solution, already filled in the reservoir bottle of 500 ml. capacity attached to microburette. Furman (1966) suggested the use of $KMnO_4$ solution diphenylamine sulfonate but authors have preferred the use of $K_2Cr_2O_7$ solution because of its sharp and distinct end point with sodium diphenylamine sulfonate. Calculate percentage of ferrous oxide from the volume of potassium dichromate required to produce the first tinge of purple colour in the solution.

Calculations

Percent FeO = Vol. of $K_2Cr_2O_7 \times 0.72$

DISCUSSION AND CONCLUSIONS

Riley (1958), Meyrowitz (1963) and Bennett and Leed (1971) suggested a total time of 10 minutes for heating (and partial boiling) to carry out complete decomposition of the rock/mineral sample. From the experimental results (Table 1) it became very clear that the heating time was longer than necessary for complete decomposition of the sample; air, somehow, had managed to oxidize ferrous iron partially. In order to determine optimum heating time, Meyrowitz's method (1963) was applied to a "French Geochemical Standard (DR-N)" while varying the heating period from 1 to 10 minutes). The experimental results thus obtain-

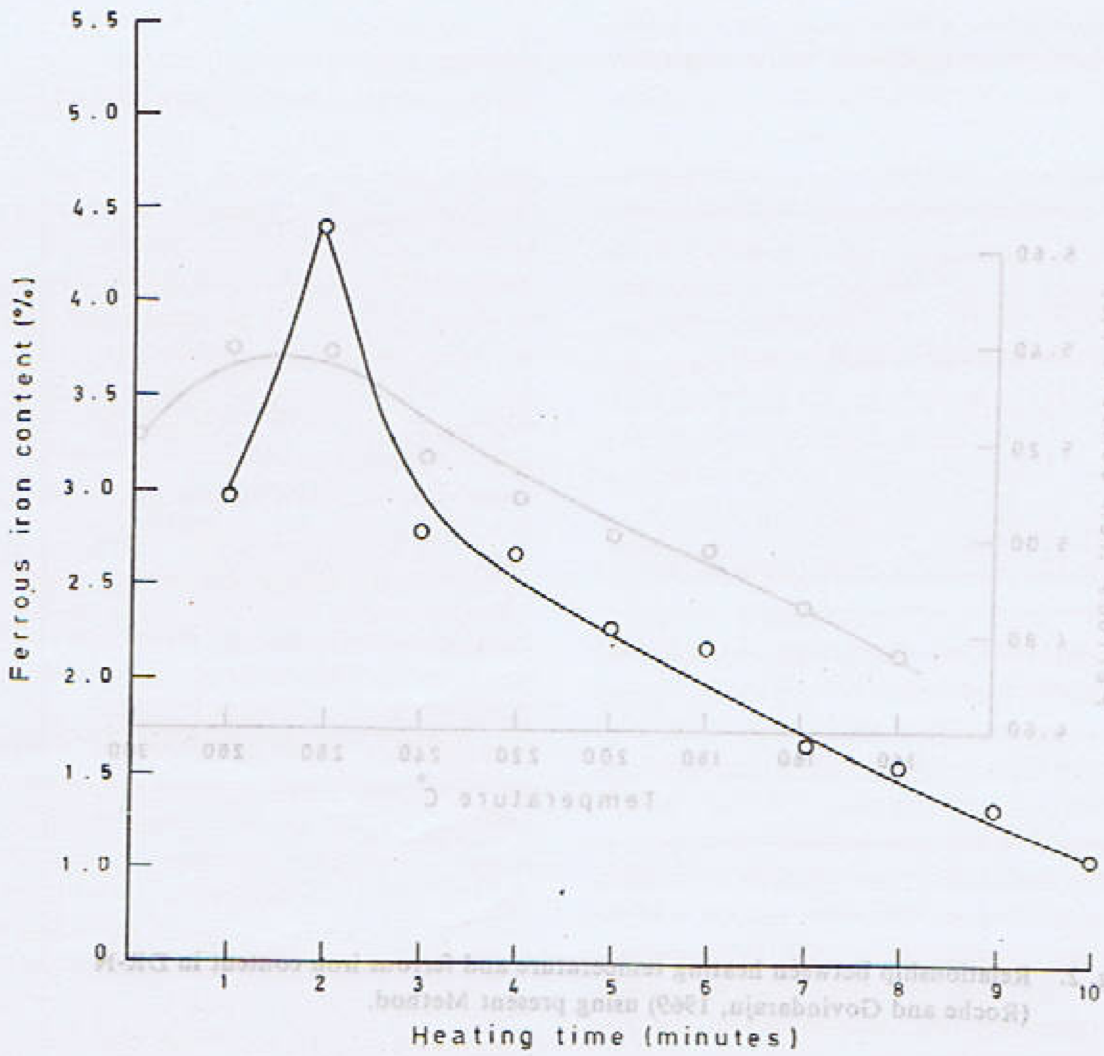

Fig. 1. Relationship between heating time and ferrous iron content in DR-N (Roche and Govindaraju, 1969) using Meyrowitz Method, 1963.

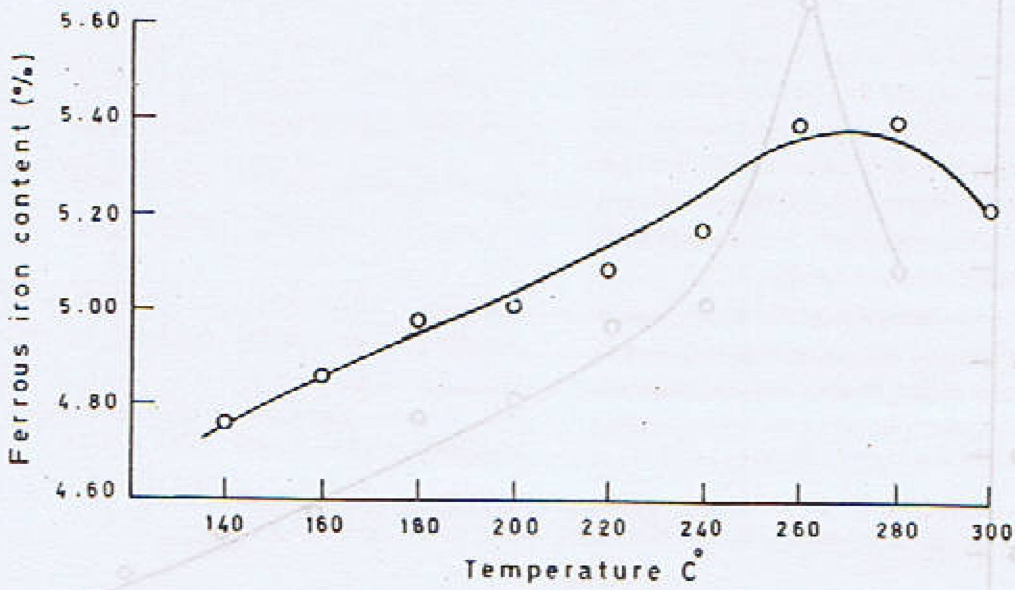

Fig. 2. Relationship between heating temperature and ferrous iron content in DR-N (Roche and Govindaraju, 1969) using present Method.

ed, have been presented in Table 2 and plotted Fig. 1, which clearly confirm the fact that a heating time of two minutes is optimum.

The same "French Geochemical Standard (DR—N)" was subjected to acid decomposition according to the present method while varying the heating temperature 140°C to 300°C to ascertain its optimum value, however, heating was carried out for an optimum time of two minutes throughout these observations. The experimental results, thus obtained, have been presented in Table 3 and plotted in Fig 2, which certainly confirm that the heating temperature of 270±10°C is optimum.

It was concluded from the above results (Fig 2) that above 280°C internal oxidation due to the decomposition of sulfuric acids starts which is responsible for low value of ferrus iron content, whereas below 260°C the decomposition of the sample remains incomplete which leads to inaccurate ferrous iron values.

TABLE 2

Effect of heating time on the contents of Ferrous Iron in DR-N with a recommended Fe 0 value=5.42% (Roche and Govindaraju, 1969) using Meyrowitz Method, 1963.

Heating Time (Temp. =360°F)	Ferrous Iron Contents (%) Observed values			Mean Value	Oxidized FeO(%) Deviation from the recommended value.
Minutes	1	2	3		
10	0 57	0.86	1.15	1.03	−4.39
9	1.25	1.30	1.38	1.31	−4.11
8	1.50	1.48	1.58	1.52	−3.90
7	1.63	1.65	1.70	1.66	−3.78
6	2.10	2.10	2.15	2.12	−3.30
5	2.20	2.25	2 30	2.25	−3.17
4	2.58	2.60	2.68	2.62	−2.80
3	2.69	2.78	2.88	2.78	−2.64
2	4.32	4.32	4.46	4 37	−1.05
1	2.88	2.88	2.98	2.91	−2.51

TABLE 3

Effect of heatiag temperatures on the contents of Ferrous iron in DR—N with a recommended FeO value=5.42% (Roche and Govinaraju, 1969) using present Method.

Heating Temp. °C for 2 min.	Ferrous Iron Content (%) Observed Values			Mean Value	Oxidized FeO (%) Deviation from recommended value
	1	2	3		
140°	4.71	4.77	4.74	4.74	−0.68
160°	4.83	4.90	4.84	4.86	−0.56
180°	4.91	4.96	4.97	4.95	−0.47
200°	5.06	4.98	5.00	5.01	−0.41
220°	5.11	5.04	5.11	5.09	−0.33
240°	5.18	5.12	5.18	5.16	−0.26
260°	5.39	5 40	5.41	5.40	−0.02
280°	5.40	5 40	5 40	5.40	−0.02
300°	5 18	5.25	5.22	5.22	−0.20

As established above, two new parameters were kept constant and ferrous iron content in nine "French Geochemical Standards" determined using the present method. The experimental results thus obtained are given in Table 4, and have been found to be in good agreement with their recommended values based on the results obtained from various laboratories by different techniques.

TABLE 4

Estimation of ferrous iron content in nine "French Geochemical Standards" (Roubault *et al.* 1970, Roche and Govindaraju 1969, 1971, 1972) using present method

No.	Name Recommeded Value	Ferrous Iron Content (%) Observed Values				Mean Value	Oxidized FeO (%) Deviation from Recommended Value
1	Granite GA (1 32)	1.31	1.33	1.32		1.32	–
2	Granite GH (0.84)	0.80	0.81	0 81		0.81	−0.03
3	Basalt Br (6.57)	6.48	6.50	6.47		6.48	−0.09
4	Mica Mg (6.85)	6.77	6.70	6.74		6.74	−0.11
5	Mica Fe (19.17)	18.77	18.80	18.95		18.94	−0.33
6	Bauxite BX-N (0.29)	0.28	0.27	0.26		0.27	−0.02
7	Serpentine UB-N (2.70)	2.42	2.39	2.38		2.40	−0.30
8	Diorite DR-N (5.42)	5.39	5.40	5.41		5.40	−0.02
9	Etalon Traces VS-N (0.26)	0.25	0.24	0.24		0.24	−0.02

Thus, the present method is not only the simplest but also the quickest among those reported so far. It yields good results, fulfilling the needs of mineralogists and petrographers for the accurate estimation of ferrous iron content in non-refractory silicate rocks and minerals.

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THE PROGRESS OF PETROLOGICAL RESEARCH AT THE PUNJAB UNIVERSITY LAHORE, PAKISTAN

BY

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Abstract. *The paper gives historical review of petrological research at the Institute of Geology, Punjab, University, also including such branches as Geochemistry, Petrochemistry, Mineralogy and Economic Geology.*

INTRODUCTION

With the establishment of the Department of Mineralogy at the Punjab University in 1952, being the first of its kind in the country, the subjects of mineralogy and petrology had an unique beginning. The Department was housed in the Institute of Chemistry and the course offered was titled as "Mineral Chemistry", as a specialization for M.Sc. (Final) year students. Thus, research could be initiated right at the post-graduate (M.Sc.) level; this was in contrast with the Department of Geology, which was dealing with the first-F.Sc. (Higher Secondary School) level class of students. It was also fortunate that the Department of Mineralogy had the backing of Unesco-Pak Government protocal, and was headed by a Norwegian Mineralogist, Professor O.A. Broch Professor Broch had been an active associate of Professor Goldschmidt at Oslo who had the international recognition as the father of geochemistry. These factors could infuse a dynamic planning in the field of Mineralogy, covering the subjects of mineral chemistry, geochemistry, mineral genesis, petrology and related disciplines. As a result, when the twin departments of Mineralogy and of Geology were amalgamated in 1954, the fields of mineralogy and petrology had already developed considerably. The academic weight of this component was reflected in the very name of the integrated department, called as the Department of Geology and Mineralogy. It was in 1958, that the word Mineralogy was dropped from the title when Sectional reorganisation took place to include Palaeontology/Stratigraphy, Petroleum/Structural Geology and Geophysics. Buy that time, a geochemistry laboratory was already functioning as part of the Section of Mineralogy and Petrology. When the Department of Geology shifted to New Campus (in 1965), X-Ray laboratory, mineral separation laboratory, ore microscopy laboratory, advanced optics laboratory and a large Geochemistry was available with many items of advanced instruments. In 1979, when the Department was raised to the status of Institute of Geology, the Section of Mineralogy and Petrology, alongwith its sister section of Geochemistry, constituted the Division of Economic Geology.

Professor Broch left in 1955. In 1956, Dr. G. Zeschke (German) and in 1959, Dr. P. J. Stephenson (Australian) arrived as Uneseo Experts in the field of Mineralogy/Petrology and continued to contribute to the development of this Section. In 1962, Dr. Martin was succeeded by Professor

R G. Davies for development of Geochemisry laboratory (see Martin, 1962).

Right from 1952, strong research bias was introduced in mineralogical and petrological research. As mentioned already, this was possible as the subject was initiated at the post-graduate level. Following successful completion of the first-ever class of students, a Research Scholarship in Mineralogy was introduced that culminated into creation of research base and early publications. With fluctuations and even threat of extermination, the concept of whole-time research position survived even-though only one post exists at present. Nevertheless, it was with availability of such positions that successful Ph. D. programme could be launched by Dr. Fazalur Rahman and Dr. Shafeeq Ahmad. Mr Iftikhar Ahmad, Mr. Ijaz Hussain Uppal and Afif Tahir were the succeeding research workers in the field of mineralogy and petrology.

In the following is given summerized account of research achievements in the fields of mineralogy, petrology and related disciplines, the accounts are given on the basis of 10 years stage. Only publications already produced are referred to in the text, while some of the unpublished data and descriptions are given in the Theses/Field Reports/Research Reports listed in Shams (1982) where initiation and continuation of projects are given.

PERIOD 1951—1961

The first-ever research was undertaken on vesuvianite (idocrase) from Hindubagh (now Muslimbagh), Zhob District, Baluchistan, which had attracted attention due to its enchanting crystalline form and pistachio green colour. Its unit cell constants were determined by X-Ray diffraction method that constituted subject matter of the first publication of the Department (Shams, 1955-*a*). During this study, the mineral was found to exhibit anomalous optical properties and unique pattern of sectorial twinning. Need for study of its geometry but lack of suitable equipment lead to devising a mechanism of using Federov stage as a stage goniometer (Shams, 1956*a*); results of this study were reported also at Pakistan Science Conference (Shams, 1955-*b*, 1956-*b*).

With the availability of field transport for Unesco Expert, first field work programme was launched in 1955 that, besides producing first systematic mineral and rock collection, proved the existence of radio-active minerals in the sands of River Indus near Chilas. This work generated persistent uranium exploration programmes and lead to specific identification of uranium minerals at Darband and elsewhere (Shams, 1965 (a) ; Zeschke, 1959 ; Tahirkheli, 1960). Simultaneously, occurrences of tungsten and titanium minerals were also located during 1955 that constituted first discovery of these elements in Pakistan (Shams *et al* ; 1967-*b*).

Along Thak Valley, District Diamir, presence of a layered basic complex was also discovered. The industrial importance of dunite rock near Chilas was reported as a high grade refractory material (Shams, 1956-*c*).

With the availability of equipment, field work facilities, further staffing of the Department and introduction of semi-specialization at the M.Sc. stage, field work programmes were launched on regional scale involving M. Sc. Final year students and staff. The Section of Mineralogy and Petrology concentrated on the Mansehra area, N.W.F.P., as an extensive revision of works published by the British India survey geologists about 60 years ago. For the first time, sub-division of granites in the Mansehra area was carried out and detailed study of various litho units was undertaken as part of mapping exercise. A preliminary account of investigations was published in Number One of the newly created "Geological

Bulletin of Punjab University'' (Shams, 1961). Simultaneously, gravity study of the granitic area was carried out (Aziz, 1961), supporting the inference drawn from geological work regarding sheet-like configuration of major granitic bodies of the Hazara Himalayas and intrusive nature of younger plutons.

During 1959, Mr. B.H. King arrived as Leverhulm Research Scholar and initiated detailed work on the petrology and structure of granitic gneisses of Lower Swat. As a policy, other researchers refrained working in this area to avoid overlap, except for problems of rather local nature. One of such works was the study of emerald mineralization near Mingora (Davies, 1962) that established basis for future exploration. Manganese mineralization was located SW of Saidu Sharif and extensive clay deposits near Shah Dheri, the latter has proved of considerable economic value for ceramic industry.

PERIOD 1962—72

The year 1962 saw an historical contribution in the form of first-ever geological map of the unmapped 5600 Km² terrain between the Lower Swat and Indus River. The map (Martin *et al*; 1962), described the presence of elongated granite-gneiss anticlinical bodies alternating with synclinal parts composed of metasedimentary formations, a complex of dominantly harnblendic lithologies in NW and soda (albite) porphyries in the South. The map was incorporated *in toto* in the first-ever official Geological Map of Pakistan (Bakr *et al.* 1964). The importance of this contribution can be judged from the fact that since 1962 almost all research on the Swat and Dir areas continues to be inspired by it (Jan and Tahirkheli, 1969; Jan *et al.* 1970; Jan *et al.* 1971; Tahirkheli *et al.* 1979, Gansser, 1980 etc.) The presence of regional basic belt, called Upper Swat Hornblendic Complex and now recognised as an ophiolite belt, has been one of the fundamental basis for the application of concepts of plate tectonics (Desio, 1977, Tahirkheli 1979, Bard *et al.* 1980; Desio and Shams, 1980; Jan, *et al.* 1981-*a*).

The publication of Swat map established this region as the second major field work project. Study was made also of thermal and metasomatic reactions in a large calcareous xenolith enclosed in a sheet of granite gneiss of Manglaur (Shams, 1963-*a*).

Similarly, a short revision was made regarding the newly located Upper Swat Hornblendic Complex (Davies, 1965). A short note was published also on an inky blue beryl (Shams, 1963-*b*).

A major achievement in the Swat-map area came when attention was given to the Chamla Valley. A large syenite-nepheline syenite complex was discovered (Siddiqui, 1967) that was later mapped in detail and sampled. A major publication was made that gave essential details of lithological members of the complex, their mineralogy and chemistry (Siddiqui *et al.*, 1968), introducing many new names in Pakistan geology. Sodalite pegmatites, zircon and corundum occurrences were discovered as part of research. Careful field work followed by REE analysis (With the cooperation of Institute of Geological Sciences, London) showed the presence also of carbonatites at Naranji Kandao (Siddiqui, 1967). This constituted not only the first discovery of these unique rocks in Pakistan but in the entire length of the Himalayas. Later, this work lead to technical investigation of nepheline syenite as raw material for indigenous glass and ceramic industry. Furthermore, successful exploration for uranium was carried out by Atomic Emergy geologists and presence of economic occurrence of rare earths was discovered by agency researchers. Later, follow-up work by the Peshawar University Geology Department, on Warsak alkaline granites and Shewa-Shahbazgarhi soda porphyries created the concept of Peshawar Plain alkaline igneous province (Kempe & Jan, 1970, Kempe & Jan, 1980, Jan, *et al.* 1981-*b*). Extension of Punjab University work in the eastern regions came as further achievements, such as the discovery of an ijolite rock near Tarbela (Siddiqui, 1973) that extended the domain of alkaline plutonism in Swat-Hazara Himalayas and generated significant follow-up work Kempe, 1973).

Again under the policy of avoiding duplication with King's study of (Central) Lower Swat area, research activities were diverted towards Malakand Agency and Dir Agency (now a district of N.W.F.P.). While regional surveys continued, the ultramafic complex of Harichand was especially investigated due to its unique nature but rather restricted areal extent ; based on detailed mapping, mineralogical and petrographical work, preliminary account was published (Uppal, 1972) showing it basically an harzburgite-peridotite complex with rodingite and pyroxenite sills and a southern serpentinized margin. The latter yielded an unique example of serpentinization by deriving water from meta-argillites and undergoing volume expansion. Chromite layers with variety of structures were noted. This work had the follow-up for industrial utilization of chromite and acted as a basis for further research, such as by G.S.P. and U.S.G.S. staff. The Harichand complex has been included as part of the so-called Dargai Klippe in recent publications on theoretical rather than practical investigation (Geodynamics of Pakistan, 1979).

The importance of the basic complex of Swat was keenly felt all along, particularly in view of the thrust contact with the Palaeozoic metasediments in the South, and the occurrence of greenschist facies rocks including serpentine and talc-carbonate formation. As a result of detailed field mapping and careful petrographical work, discovery was made of glaucophane-bearing schists from near Topsin (Shams, 1972). This location of blueschists was not only the first in Pakistan but for the entire length of the Himalayas (The India discovery was made in 1977, Virdi *et al.* 1977). While on the one hand it negated the claim of non-existance of blueschist metamorphism in Himalayas (Powell *et al.*, 1974), on the other hand, it made it possible to apply the concepts of plate tectonics for the emergence of the Himalayas (Geodynamics of Pakistan, 1979). Although occurrence of andesitic-dacitic-rhyolitic volcanics in Utror, North Swat, was known for some time (Jan and Mian, 1971) yet it was only after the discovery of blueschist rocks as marker of subduction zone that the concept of Kohistan island arc was forwarded and the Patan fault Desio (1977) was designated as the Main Mantle Thrust (Tahirkheli, 1979). The study of Shams (1972), had pointed out soda activity that involved schists having already grown glaucophane amphibole ; this aspect of research had its own importance.

The project Mansehra gave rise to complete revision of old work and formulation of the concept of magmatic granitization (Shams, 1967-*a*, 1983-*b*). A detail petrological account was published on the granitic-metamorphic complex (Shams, 1969) and articles on a number of related problems were published. For instance, work on the petrochemical evolution of the granitic complex showed the increased soda activity with youngness of rocks (Shams and Rahman, 1966). At the same time, a careful study across a granite-schist contact produced a model of metasomatism for such other cases in the Himalayas (Shams and Rahman, 19(9). The extensive presence of basic minor intrusives was also brought under study and detailed mineralogical investigations showed the typical behaviour of pyroxenes in the tholeitic magma of the Hazara Himalayas (Shams and Zulfiqar, 1968). During engagements in the Mansehra area, some specialized studies were also undertaken, such as estimation of temperatures of formation of granitic rocks by feldspar geothermometry (Shams and Rehman, 1967-*a*), growth of chess-board albite (Shams, 1967-*b*), petrology of chloritoid and staurolite-bearing rocks(Shams, 1967-*c*), mineral differentiation in crenulated schists (Shams, 1965-*b*), thermal metamorphism of calcaseous modules (Shams, 1963-*a*).

At the same time, some of the researches were unique in their wider application. For instance, with the assistance of Australian National University, Canberra, K/Ar radiometric ages were published (Shams, 1967-*d*) on micas of the Mansehra granite and Susalgali gneiss as members of the Older group of the Hazara granitic complex and of Hakale tourmaline granite as representative of the Younger group. It happened to be the first-ever absolute age data published on granites of the Pakistan Himalayas, that also established the pre-Himalayan status of the granitic complex. Later work established its Cambrian age and was reconsigned as a part of the Lesser Himalayan cordierite granite belt that occurs all along the length of the orogen (Le Fort *et al.*, 1979). The Mansehra studies also gave rise to discovery of tungsten-molybdenum minerals, North of Oghi (Shams and Rahman, 1966-*a*) and argentiferous galena near Sobrah (Shams, 1963-*c*) which was also subjected to self-potential investigation (Rahman, 1964). In the North of Darband, unique occurrence of kyanite pseudomorphs after andalusite was discovered (Shams, 1964-*a*, 1965-*c*), that constituted the then fourth known world location.

The work initiated in the Zhob Valley, Baluchistan, infact had opened the southern Pakistan for further researches. Following an unusual engagement of the Mineralogy-Petrology staff in a gravity study of the Quetta and Mastung Valleys (Siddiqui 1961), regional petrological and specific mineralogical work was initiated. Original mapping of the Palak Lara area, Splaitorgarh, produced a detailed account of rock types which were actually representative of such other occurrences in the Zhob Valley ultramafic complex (Zulfiqar and Chaudhry, 1969). On the mineralogy side, attention was concentrated on chromite due to the area being an important ore producing district of the country. On the basis of structures shown by chromite-bearing serpentinites, especially the globular (drop-in-drop) relationship, validity of liquid immiscibility was proved as an important concept in ultramafic complexes (Shams, 1964-*b*). This was earlier than significant international thinking on such lines in similar complexes. On the other hand, considering the problems involved in chemical analysis of refractory chromite mineral, particularly in ore-beneficiation operations, an improved analytical scheme was developed with considerable success (Shafeeq, 1969). In the same context, specialized studies of chromite were carried out such as, chemical composition and magnetic response of chromite (Shams and Shafeeq, 1972) and effect of heat on FeO content of chromite (Shafeeq, 1972). During course of field work in Muslimbagh, a high ferric-chromite occurrence was discovered and description was given of hydromagnesite as the first known occurrence from Zhob Valley (Shams, 1965-*d*).

Other important works during this period were statistical analyses of Si-Al relationship in Mg-Fe olivines (Shams, 1966-*d*) and the determination of gold in some sulphide ore samples by radiochemical and neutron activation methods (Rahman, 1972-*b*). It may be worth mentioning that the presence of gold in boulangerite from Chitral was reported for the first time by Siddiqui (1969).

Regional studies of Dir Malakand and Chitral areas were initiated by Dr. Nawaz, who produced large volume of research.

A new project area opened during this period concerned the Kirana Hills Group, District Sargodha, Punjab. These hillocks, with main Kirana as the largest, are the outliers of among the oldest rocks of basement and recognised to belong to the Aravalli system. The old work of Heron (1913) was subjected to revision, including detailed sub-division of volcanic rocks and their mineralogical, petrographical and chemical characterization, including trace elements study and large scale mapping.

PERIOD 1973—1983

During this period, research activities continued to be concentrated in the Mansehra, Swat and Muslimbagh areas and a stream of publications appeared on various mineralogical and petrological aspects of the rock complexes. On the other hand, projects initiated during the proceeding decade in Dir, Malakand and Northern Areas were matured. This period, therefore, saw progressively decreasing activities in the previous areas of research projects and increasing activities in the areas brought under investigation during the previous decade. At the same time, entry into the Northern Areas, initiated in 1955 and consolidated in 1^68, was extended further with fruitful achievements.

In the Mansehra area, work was extended northwards towards River Indus and covering even some such parts that had remained almost obscure geologically. A number of publications originated from detailed work on acid minor bodies, inspired from their preliminary studies during previous decade. Pegmatites, aplite, albitites, quartz, quartz-ilmenite and quartz-kyanite veins were described in the background of classifications (Ashraf and Chaudhry, 1976 *a, b,c,d*) and petrogenetic studies of the acid minor bodies of Mansehra and Batgram area (Chaudhry *et al.*, 1974 a, b, c). These studies produced the most exhaustive contribution on acid minor bodies associated with a major granitic complex of the Pakistan Himalayas, therefore, having regional implications. In this manner, the research initiated on the Hazara granitic complex in 1960 was taken to its highest stage and producing intensive detail. Much field and laboratory data was collected on problems of restricted field extent also but of considerable importance. For instance, description was published of a chromian-muscovite from a complex aplite (Ashraf *et al.*, 1977), chess-board albite(Ashraf *et al.*,1976-*d*), obliquities of potash feldspar (Shams, 1978-*a*) and mechanical standardization of the so-called "clay" as alteration product of Susalgali gneiss (Shams, 1978-*b*). A study of particular importance concerned the Chitti Dheri porphyry as the occurrence of material of anatectic origin, proving it as the ultimate product of granitization of the metasediments, and having acted as parent to the Younger group of tourmaline granites and acid minor bodies (Shams, 1980).

An important extension of the Mansehra work concerned the Lahor granitic complex and the associated rocks (Chaudhry *et al.*, 1980-*f*). This study was significant in locating skarn-type mineralizations of lead, molybdenum, zinc, tungsten and minor dissemination of tin and silver etc. (Chaudhry, *et al*, 1980-*b, f*, Chaudhry, 1982); the work continues to generate considerable exploration activity by public sector agencies of mineral development. An oblique extension of the granite-project concerned the Nanga Parbat massif that had been made a classic example of batholithic granitization by (Misch, 1949). In view of lack of modal and chemical data in the previous study, these aspects were taken up and chemical nature of metasomatism defined (Shams and Shafeeq, 1980). This study also permitted a comparative modal investigation of granitic complexes of NW Himalayas in Pakistan, including new data on Swat granites (Saleemi, 1978). Much of the data collected in field and having originated from laboratory work remained to be published in future.

While working on the outer and adjoining regions of Lower Swat (toposheet No 43 B), leading to discovery of alkaline complex in Chamla and blueschist in Topsin area, Ambela granitic complex in South was brought under petrochemical investigation (Shafeeq and Zulfiqar, 1974). The Malakand project had expanded into Dir district, being rather an almost virgin area like the Swat district, research work involved original geological-lithological mapping and petrographic description of main units. Detailed description of mapped areas were produced of Sahibabad-Bibior (Chaudhry, Aftab and Shafiq, 1974), Khagram (Chaudhry and A.G. Chaudhry, 1974-*d*), Timurgara-Lal Qila (Chaudhry, Kausar and Lodhi, 1974-*f*), and Malakand (Chaudhry, Jaffery and Saleemi, 1974 (*c*) ; Chaudhry, Ashraf, Hussain and Iqbal, 1976). In this manner, a vast region became geological familiar and base was established for follow-up specialized research. However, the most significant achievement was the discovery of carbonatites from Silai Patti, Malakand (Ashraf *et al.*, 1977) that extended Westwards the regime of the Chamla syenite-carbonatite complex. On the other hand, detailed study of Malakand granite-gneiss complex was another important contribution, as a continua tion of the Mansehra and the Swat granite studies (Chaudhry *et al.*, 1974 (*a*), 1976).

The basic (ophiolitic) belt of Swat and Dir continued to attract attention, generating some specialized studies as well. The Dir amphibolites, as southern marginal belt of the basic complex, were subdivided as orthoamphibolites and para-amphibolites and given detailed treatment (Chaudhry *et al.* 1974-*g*). A body of spinel lherzolite rock was discovered from Swat and besides its mineralogy and petrology (Zulfiqar and Shafeeq, 1974), its spinel phases were studied by electron microprobe method (Zulfiqar, 1977).

Specific mineralogical investigations concerned garnets from gneisses and pegmatities of Upper Swat Hornblendic Group (Zulfiqar and Shafeeq, 1975) and minerals of the Topsin blueschists (Shams 1979, *et al.*, 1980-*b*). With the cooperation of British Museum Natural History and Institute of Geological Sciences, London, chemistry of glaucophane amphibole was determinad showing it to be crossite ; its age was also estimated by K/Ar method to exactly date the subduction phenomena in Swat Himalayas (Shams, 1980 ; Desio and Shams, 1980) and computing the rate of north ward drift of the Indo-Pak plate.

Significant research was done on chromites both from Muslimbagh and from Harichand/ Sakhakot. In the case of Muslimbagh chromites, such studies carried out as, correlation of unit cell dimensions and chemical compositions (Shams and Shafeeq, 1978), effect of grain size and groundmass on determination of microhardness (Shafeeq, 1977-*a*), geochemistry in general (Shafeeq, 1976 *a*, *b*, 1978 *a*) and of one ore body in special (Shafeeq, 1978 (*c*) and their physical properties (Shafeeq, 1978*b*). Similarly, Harichand chromites were studied for their geochemistry (Shafeeq, 1976-*b*), alteration (Zulfiqar *et al.*, 1981) and megascopic structure (Zulfiqar, 1982). A corrolary of these works is the study of heating on ferrous iron determination during silicate analysis (Rahman *et al.*, 1978).

Certain petrological studies continued in the previous areas of regional-project status. For instance, a suite of soda dolerites from Muslimbagh were described to minute detail (Shams and Shafeeq, 1976). Similarly, geology of the serpentinite belt and of associated rocks was described from North of Muslimbagh (Siddiqui *et al.*, 1974). Petrology of the Taghma area from Swat also was subjected to detailed study (Zulfiqar, 1978).

In the Northern Areas, a comprehensive study was made of the Thak Valley igneous complex (Shams, 1975) showing its subdivision into Noritic Group and Dioritic Group and petrochemical variation trend in comparison to world occurrences. This study was followed by further work on various aspects of the complex, such as detailed petrochemistry (Shams and Shafeeq, 1979) and ore microscopy (Shafeeq, 1980). The area of study extended northwards to Thelichi (Zulfiqar *et al.*, 1977) and included ore microscopy of associated sulphides (Shafeeq, 1978-*d*). Towards south, an important study was made of Babusar area (Zulfiqar *et al*., 1976) that defined the complicated lithological framework of southern edge of the basic (ophiolite) belt of Thak Valley. During Thak Valley work, another important achievement was the location of a sheared serpentinite lens, taken to be marking an old tectonic suture ; globular magnetite is an important constituent besides, talc, cenbonate, and anthophylite.

Southwards of Babusar, the serpentine mass of Soch was mapped and sampled, showing presence of nickel mineralization. The latter was also discovered in many altered basic-ultrabasic rocks of Swat and Dir (Chaudhry *et al.*, 1980-*b*) and in the Sakhakot—Qila complex associated with chromite (Zulfiqar *et al*, 1982). Molybdenum mineralization in Swat Kohistan, magnetite in Lower Hazara Kohistan (Chaudhry *et al.*, 1980-*c*), pyrite-pyrrhotite-chalcopyrite from Pattan Kohistan (Siddiqui, 1977), lead and zinc mineralization associated with Labor granite (Chaudhry, 1982) etc. were among some works arising from economic mineralogy projects. An unique achievement in the Sakhakot-Qila complex was the discovery of awaruite, iridian awaruite, and a new Ru-OS-Ir-Ni-Fe alloy (Zulfiqar *et al.*, 1981).

During this period, attention was also diverted to Azad Kashmir for regional studies. For instance, Middle Siwalik rocks of Kotli area (Chaudhry *et al*, 1981-*a*) metamorphic rocks of Mauji and Reshian areas of Muzaffarabad (Chaudhry *et al.*, 1981-*b*), volcanic rocks of Poonch District (Chaudhry *et al.*, 1980-*a*) and clay bauxite and clay deposits of Kotli (Ashraf *et al*, 1980) were some major projects accomplished. Most of these works had economic geology bias, extended also to Kohat District of N.W.F.P. for its bentonite deposits (Chaudhry *et al.*, 1977-*a*) and also clays from Hub dam area, near Karachi (Chaudhry,1977-*b*). Study of copper mineralization near Baldher, Haripur, was significant as a discovery (Shams *et al.*, 1974).

The period also saw attempts to tie mineralogical-petrological data and wide field observation on regional scale in terms of concepts of plate tectonics. For instance, an interpretation was made of petrotectonic assemblages West of Himalayan syntaxis on the basis of Dir, Swat and Upper Hazara studies (Chaudhry *et al.*, 1980-*c*). Specific plate tectonic model for NW Himalayas was proposed (Chaudhry *et al.*, 1983-*a*), also for the sake of regimes of uranium mineralization (Shams, 1983-*a*).

This period also saw a new dimension of research activity when staff of Mineralogy/petrology lead geological expeditions to Northern Pakistan, with fruitful results.

The first Expedition was staged in 1974 when Professor F.A. Shams lead a team of 14 geologists including colleages, staff and young post-graduates from other universities. The Expedition was organised by Pakistan Science Foundation and was intended to benefit from newly constructed (partly under construction) Karakorum Highway. Traverses were made in almost all major parts of Northern country, such as Hunza Valley, Yasin Valley, Astor Valley, Shigar Valley, Upper Indus Valley, Bagrot Valley and Barr Valley, etc; cross-country excursions were done on either sides of these Valleys. As a result, considerable part of the Northern Areas was brought under reconnaissance survey. Extensive field data, samples of rocks and ores were collected and many areas were prospected for economic minerals. Copper, zinc, iron and lead ores, semi precious stones, radioactive minerals, decorative stones, micas, asbestos, soapstone, alum and a number of industrial rocks and minerals were discovered or investigated in detail. Petrotectonic and inter-orogenic relations between Himalayas and Karakorum were taken into study and lithotectonic features of Indus and Shigar-Chalt sutures were investigated. This was first-ever national Expedition to the Northern Areas, much earlier than the 1980 international Expedition staged by British Geographical Society. The Expedition lead to future field projects for detailed work on specific problems, involving M.Sc. (Final) year students as well.

During the Summer of 1982, another Expedition was lead by Professor Shams to Baltistan in the remote NE part of the country, mainly mapping and sampling the northern side of the Shigar Valley. A new geological map was produced and some useful mineral locations were identified. This Expedition was funded by Punjab University and the Pakistan Science Foundation ; the programme will continue for some time.

An yet another regional project was launched during the summer of 1983 lead by Professor Shams and aimed at economic geological survey. The project, funded by U.G.C. Karakorum Research Cell, lead to many useful mineralogical studies and prospecting achievements Reports of these expeditions were submitted to relevant quarters and papers arising therefrom were published (see references and Shams, 1982)

During the period under review, many externally funded research projects were undertaken by Min-Pet staff, such as Sakhakot-Qila ultra-mafic complex project (Zulfiqar), Salt Range project (Shams and Shafeeq) D G. Khan Pezu iron ore projects (Shams) and Salt-Range gypsum project (Shams and Shafeeq). Reports were submitted to concerned agencies (see Shams, 1982).

The period also saw major publication efforts, aiming at production of monographs. One project concerned an international monographs on Granites of Himalayas, Karakorum and Hindukush, edited by F.A. Shams. Composed of 24 papers from 36 leading scientitists of 10 countries, the book stood as a milestone with latest geological data on these three orogens, their stratigraphy, petrology, geodynalmics and mineral potential in relation to granitic-gneissic complexes. 3 papers were contributed by staff of the Institute, two by Shams on granits of NW Himalayas and on uranium mineralization while one by Chaudhry and Shams on Shewa porphyries as part of Peshawar plain alkaline igneous province Chaudhry *et al* 1983-*b*).

Another monograph concerns the Ophilites of Pakistan, drawing heavily from researches of Shams, Zulfiqar, Shafeeq and Chaudhry, and incorporating data from other sources.

Another international monograph was initiated on Ophiolites of Himalayas, Karakorum and Hindukush, editor F. A. Shams ; it is planned to be published in 1985.

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SUBSURFACE PETROGRAPHIC INVESTIGATIONS OF JOINTINGS IN SELECTED CORE SECTIONS FROM NURYAL NO. 1 WELL, PAKISTAN

BY

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Abstract : *The paper describes the petrographic methods for the determination of jointy parameters such as volume density of joints, jointy porosity and permeability, and their application on selected core samples from Nuryal No. 1 Well drilled in Potwar region of Punjab province.*

Jointy parameters were determined on Jurassic variegated clastics, Paleocene Patala-Khairabad limestone, Eocene Nammal Shale, Eocene Sakesar-Chorgali limestone, Miocene Fatehjang limestone and Miocene Murree clastics as shown in tables 1-3. Effective reservoir beds are present in Khairabad, Sakesar and Chorgali limestones, fairly effective potentiality in Jurassic variegated clastics and the remaining Patala, Nammal, Fatehjang and Murree racks have mostly ineffective reservoir capacities as shown in tables 1 to 3.

Jointy porosity and permeability data were previously obtained on clastic rocks of Lower Ranikot and Limestones of Upper Ranikot, Laki and Khirthar formations belonging to Paleocene and Eocene ages from selected core sections of Hundi No. 2 Well and Khothar No. 1 Well, located in the north-eastern portion of Karachi trough area near Thana Bula Khan in Dadu district of Sind province (Shuaib, 1972 and 1973).

Petrographic investigations of jointings indicate that Paleocene Khairabad limestone and Eocene Sakesar-Chorgali limestone in Potwar region of Punjab province contain effective reservoir beds whereas their equivalents Ranikot and Laki rocks near Thana Bula Khan in Dadu district of Sind province have only fairly effective reservoir beds and so lack effective reservoir potentiality. Positions of Nuryal-1, Hundi-2 and Khothar-1 Wells are shown in Figure-1.

INTRODUCTION

The idea of the study of rock jointing in the petro-graphic section of the Geological and Analytical laboratories of Oil and Gas Development Corporation was initiated by consultant chief geologist L.K. Teplov and consultant on reservoir properties of rocks J.A. Bourlakov in 1971. This paper is based on the methods and procedures adopted by Russian geologists to determine jointy parameters such as volume density of joints, jointy porosity, jointy permeability etc. fissured reservoirs since 1955 (Smekhov and Bulach, 1962).

Oil and gas reservoirs are divided into two main types namely granular and jointy. Granular reservoirs are generally sandy-silty rocks characterised by intergranular porosity, Some limestone and dolomite with oolitic, intercrystalline and inter-granular porosity may be classified as reservoirs of granular type. The jointy type reservoirs can be particularlly any rock with rigid bond which have undergone the effects of tectonic forces, weathering, leaching, crystallization etc. and are broken by joints.

The object of the comprehensive study of fissured reservoirs is to determine the nature of joints, direction and magnitude of tectonic forces, effects on porosity and permeability and correlation of rocks. Oil and gas fields are connected with fissured reservoirs and in spite of the fact that the reservoir rocks have low intergranular permeability, they produce high flow of oil and gas because of the presence of joints in rocks. The known methods for the determination of jointings are geological, geophysical and hydrodynamic. This paper deals only with the petrographic study of joints in large thin sections from selected core samples of Nuryal No. 1 Well, located near village Dhok Nuryal in Potwar region of Punjab province. The well was drilled down to a depth of 4806 metres and penetrated upto Variegated series of Jurassic age.

METHOD

Slices were cut by cutting machine, perpendicular to the bedding planes selected core specimens at different intervals according to the change in lithology and jointing intensity. Large thin sections were made from these slices for the following petrographic study of joints.

Nature of Joints :

Joints may be horizontal, vertical, chaotic etc. with reference to bedding planes. They may be partially or completely filled either by mineral constituent or bitumen or both. It is possible that joints may not be filled by any constituent and remain open. Joints filled by mineral constituents are not considered but only open and bitumen filled joints are measured for the calculation of effective porosity and permeability. Average width of microjoints is calculated by taking the mean value from several measurements of the thickness of the open or bitumen filled joints at appropriate intervals which seldom exceeds greatoer than 0 1 mm (100 u). Width of joints 0.001 to 0 01 mm (1-10 u) is considered narrow, 0.01 to 0 05 mm (10-50 u) as medium and 0.5 mm to 0.1 mm (50-100 u) as wide. Length of microjoints is considered as very short if less than 1 mm, short 1-25 mm, medium 25-50 mm and greater than 50 mm as long.

Thin sections may contain artificial joints formed during the preparation of thin sections, which are to be distinguished from natural joints. Sides of artificial joints are fresh and broken with generally spreading outline and mostly at the edges of thin sections.

Volume density of joints :

Volumetric density of joints is a criteria of rocks fracturings which is calculated from the following formula :—

$$T = \frac{\pi . l}{2 \, S} \text{ where}$$

'T' is volume density of joints, $'\pi' = \frac{22}{7}$, 'l' is the total length of joints present, 'S' is the area of rock section. It is preferred that 'T' is calculated per metre.

Volumetric density of joints less than 50 per metre is considered as poor, 50 to 100 as moderate and greater than 100 as high.

Jointy porosity :

Total porosity of jointy rocks consists of intergranular porosity, porosity due to the presence of open or bitumen filled joints and volume of voids present. Fractured limestones generally have voids of different dimensions. Voids are considered as very fine if the average diameter is between 0.01 to 0.1 mm, fine between 0.1 to 0.25 mm, medium between 0.25 to 0 50 mm, large between 0 5 to 1 0 mm and coarse 1.0 to 2.0 mm. Voids having diameter greater

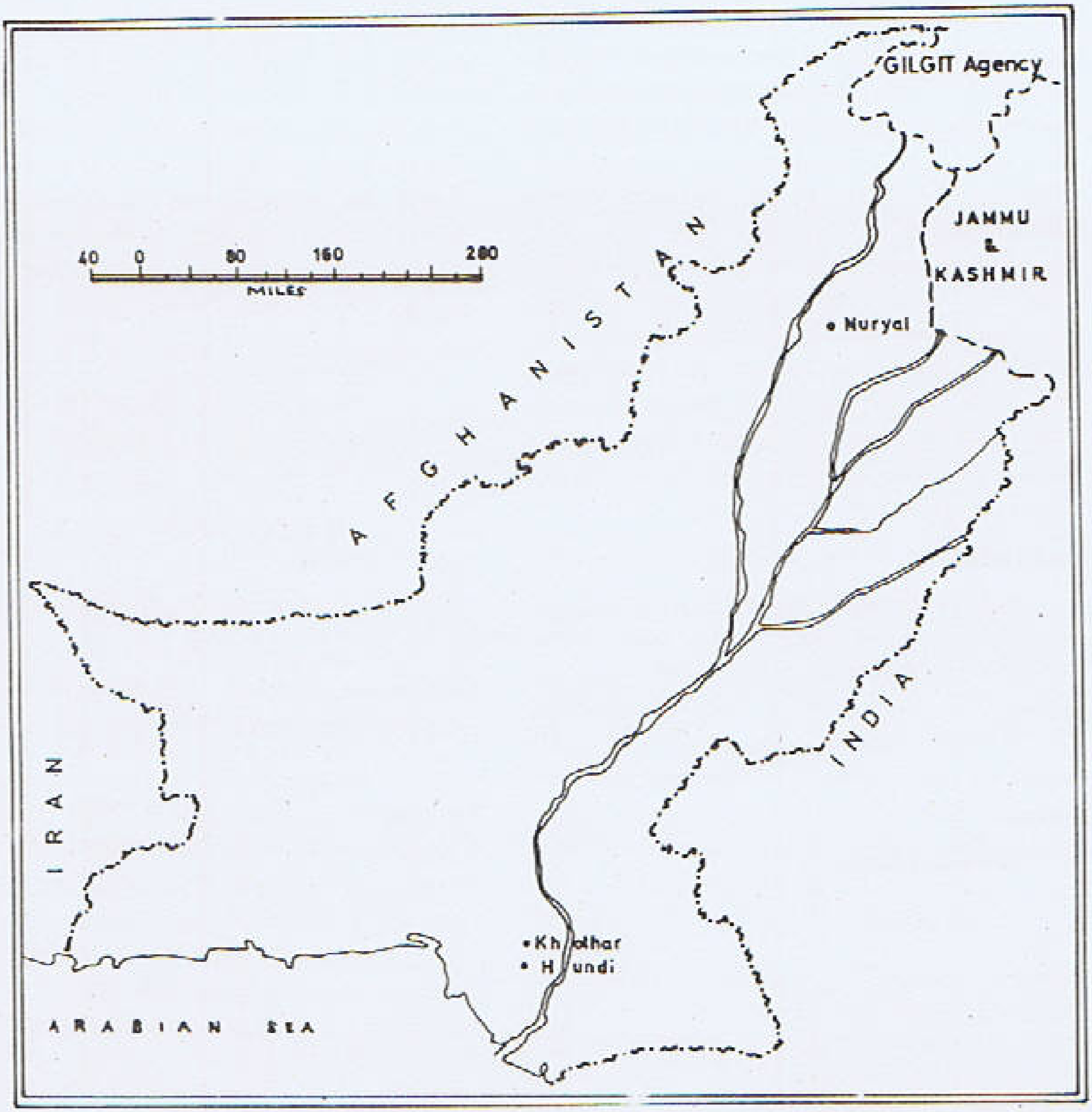


Fig. 1. MAP OF PAKISTAN SHOWING THE POSITION OF NURYAL-1 HUNDI-2 AND KHOTHAR-1 WELLS

TABLE 1

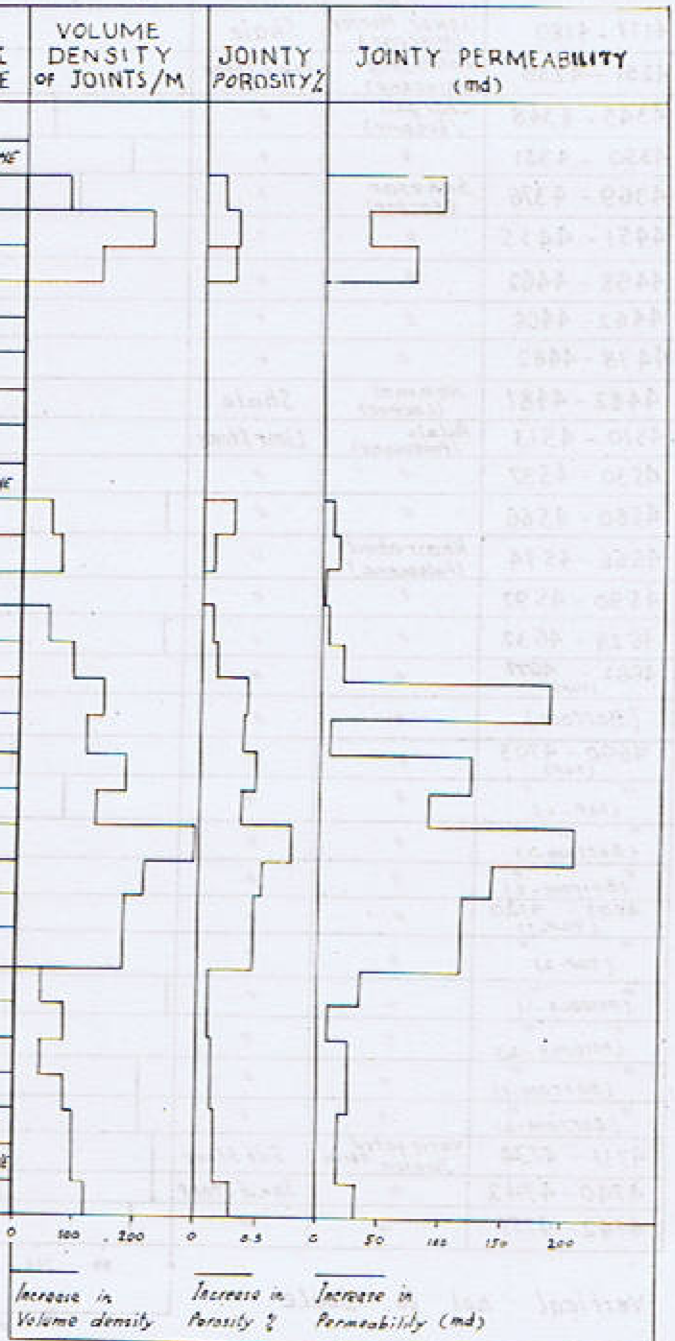
JOINTY PARAMETERS OF SELECTED CORE SECTIONS FROM NURYAL WELL NO. 1

Core No.	Depth in meters.	Formation and age.	System of jointing.	Area of Slide in mm^2 (S) (Horizontal X vertical)	Length of joints mm (l)	Average width of opening in joints in mm (b)	Volume density per meter (t)	Jointy porosity % (mj)	Jointy permeability in (kj) md.	Brief Petrography
1	4176.63—4180.18	Lower Muree (Miocene)	Chaotic	25×15	—	Nil	—	Negligible	Negligible	**Shale :** Purple, hematitic highly calcareous, silty sandy.
2	4250.60—4255.82	Fatehjang zone (Miocene)	—do—	25×15	—	Nil	—	—do—	—do—	**Lime stone :** Light pinkish and grey, micro-nodular fossiliferous.
3	4344.90—4347.50	Chorgali (Eocene)	Inclined	30×15	20	0.04	70 (=)	0.18 (=)	96.7 (≡)	**Lime stone :** Grey massive, unfossiliferous, bituminous often associated with anydrite.
5	4350.43—4351.13	—do—	Horizontal	20×30	80	0.02	210 (≡)	0.27 (=)	36.3 (=)	—do—
6	4396.47—4375.75	Sakesar (Eocene)	—do—	30×20	50	0.03	131 (≡)	0.25 (=)	76.5 (≡)	**Limestone :** Grey microgranular, bituminous fossiliferous.
10	4450.82—4454.82	—do—	—do—	20×25	—	Nil	—	Negligible.	Negligible.	**Limestone :** Grey to dark grey, microgranular, bituminous fossiliferous.
11	4458.26—4461.96	—do—	—do—	30×30	—	Nil	—	—do—	—do—	—do—
12	4461.96—4465.96	—do—	—do—	25×25	—	Nil	—	—do—	—do—	—do—
13	4478.24—4482.04	—do—	—do—	20×20	—	Nil	—	—do—	—do—	—do—
14 (35 Cm.) above bottom).	4482.04—4486.71	Nammal (Eocene)	—do—	25×15	—	Nil	—	—do—	—do—	**Shale :** Grey, fissile, bituminous, fossiliferous, highly calcareous. siliferous.
15	4510.20—4513.30	Patala (Paleocene)	—do—	25×25	—	Nil	—	—	—	**Limestone :** Grey, somewhat fissile, granular, bituminous, glauconitic, highly argillaceous, fossiliferous.
16	4529.83—4537.34	—do—	—do—	25×15	10	0.01	42 (—)	0.26 (=)	0.9 (—)	—do—
17	4560.09—4566.09	—do—	—do—	20×25	20	0.02	63 (=)	0.08 (—)	10.9 (=)	**Limestone :** Grey, microgranular, bituminous, fossiliferous.
18	4566.09—4574.34	Khairabad (Paleocene)	—do—	20×20	—	Nil	—	Negligible.	Negligible.	**Limestone :** Grey to dark, micro-granular, bituminous, fossiliferous.
19	4590.07—4597.22	—do—	—do—	20×20	1.0	0.01	39 (—)	0.03 (—)	0.9 (—)	**Limestone :** Gray to dark grey, micro-granular, bituminous, fossiliferous.
21	4624.06—4632.39	—do—	—do—	20×15	15	0.02	79 (=)	0.1 (=)	13.6 (=)	—do—
23 (Top)	4662 to	Khairabad	—do—	35×15	45	0.04	135 (≡)	0.34 (≡)	187.6 (≡)	—do—
(Bottom)	4677	(Paleocene)	Chaotic	35×20	45	0.01	101 (≡)	0.06 (−)	1.1 (−)	—do—
24 (Top)	4690	—do—	—do—	50×25	140	0.04	176 (≡)	0.45 (=)	121.8 (≡)	—do—
	to	—do—	—do—	50×35	135	0.04	121 (≡)	0.31 (=)	8.4 (≡)	—do—
(Bottom)	4703	—do—	—do—	40×40	300	0.04	295 (≡)	0.75 (≡)	205.2 (≡)	—do—
(Bottom)		—do—	—do—	45×35	200	0.04	200 (≡)	0.51 (≡)	139.0 (—)	—do—
25 (Top)	4703	Khairabad (Paleocene)	Chaotic	50×30	160	0.04	168 (≡)	0.43 (=)	116.7 (≡)	**Limestone :** Grey to dark grey, micro-granular, bituminous, fossiliferous.
—do—		—do—	—do—	45×32	155	0.04	169 (≡)	0.43 (=)	117.8 (≡)	
(Middle)	to	—do—	—do—	20×20	10	0.02	39 (−)	0.05 (−)	3.4 (−)	—do—
—do—		—do—	—do—	20×25	25	0.01	79 (=)	0.05 (−)	0.9 (−)	—do—
(Bottom)	4720	—do—	—do—	40×25	25	0.04	39 (−)	0.10 (=)	27.4 (=)	—do—
26 (Top)	4731 to 4734	Variegated Series (Jurassic)	Horizontal	45×40	110	0.02	96 (=)	0.12 (=)	16.7 (=)	**Siltstone :** Grey, noncalcareous, carbonaceous, argillaceous.
27 (Top)	4740 to 4742	—do—	—do—	50×35	100	0.02	90 (=)	0.11 (=)	15.6 (=)	**Sandstone :** Light to dark, grey, noncalcareous, silty, very fine to fine sandy sizes.
28 (Top)	4742 to 4751	—do—	Choatic	50×35	120	0.03	108 (≡)	0.21 (=)	31.7 (=)	**Sandstone :** Whitish to grev, noncalcareous mainly fine sandy size, quartz.

Volume density per meter.	Proportion	Symbol	Jointy porosity %	Proportion	Symbol	Jointy permeability (md)	Proportion	Symbol
< 50	Poor	(−)	< 0.1	Poor	(−)	< 5	Ineffective	(−)
50—100	Fair	(=)	0.1-0.5	Fair	(=)	5—25 25—50	Poorly effective-Fairly effective	(=)
> 100	High	(≡)	> 0.5	High	(≡)	> 50	Effective	(≡)

TABLE. 2. LOG REPRESENTATION OF VOLUME DENSITY OF JOINTS PER METER, JOINTY POROSITY & JOINTY PERMEABILITY OF SELECTED CORE SECTIONS FROM NURYAL WELL-I

DEPTH IN METERS	FORMATION & AGE	ROCK NAME
4177 - 4190	Lower Murree (Miocene)	SHALE
4251 - 4256	Fatehjang (Miocene)	LIMESTONE
4345 - 4348	Chorgali (Eocene)	"
4350 - 4351	"	"
4369 - 4376	Sakesar (Eocene)	"
4451 - 4455	"	"
4458 - 4462	"	"
4462 - 4466	"	"
4478 - 4482	"	"
4482 - 4487	Nammal Eocene	SHALE
4510 - 4513	Patala Paleocene	LIMESTONE
4530 - 4537	"	"
4560 - 4566	"	"
4566 - 4574	Khairabad Paleocene	"
4590 - 4597	"	"
4624 - 4632	"	"
4662 - 4677 (top)	"	"
" (bottom)	"	"
4690 - 4703 (top - 1)	"	"
" (top - 2)	"	"
" (bottom - 1)	"	"
" (bottom - 2)	"	"
4703 - 4720 (top - 1)	"	"
" (top - 2)	"	"
" (middle - 1)	"	"
" (middle - 2)	"	"
" (bottom - 1)	"	"
" (bottom - 2)	"	"
4731 - 4734	Variegated series Jurassic	SILTSTONE
4740 - 4742	"	SANDSTONE
4742 - 4751	"	"



Vertical not to Scale

TABLE 3. LOG REPRESENTATION OF JOINTY PERMEABILITY & RESERVOIR CAPACITY OF SELECTED CORE SECTION FROM NURYAL WELL.1

Depth in meter	Formation & Age	Rock name	Jointy Permeability (md)	Reservoir Capacity
4117 - 4180	Lower Murree (Miocene)	Shale		Ineffective
4251 - 4256	Fatehjang (Miocene)	Lime Stone		"
4345 - 4348	Chorgali (Eocene)	"		Effective
4350 - 4351	"	"		Fairly effective
4369 - 4376	Sakesar (Eocene)	"		Effective
4451 - 4455	"	"		In effective
4458 - 4462	"	"		"
4462 - 4466	"	"		"
4478 - 4482	"	"		"
4482 - 4487	Nammal (Eocene)	Shale		"
4510 - 4513	Patala (Paleocene)	Lime Stone		"
4530 - 4537	"	"		"
4560 - 4566	"	"		Poorly effective
4566 - 4574	Khairabad (Paleocene)	"		In effective
4590 - 4597	"	"		"
4624 - 4632	"	"		Poorly effective
4662 - 4677 (Top)	"	"		Effective
(Bottom)	"	"		In effective
4690 - 4703 (Top)	"	"		Effective
" (Top - 2)	"	"		"
" " (Bottom - 1)	"	"		"
" " (Bottom - 2)	"	"		"
4703 - 4720 (Top - 1)	"	"		"
" " (Top - 2)	"	"		"
" " (Middle - 1)	"	"		In effective
" " (Middle - 2)	"	"		"
" " (Bottom - 1)	"	"		Fairly effective
" " (Bottom - 2)	"	"		"
4731 - 4734	Variegated Series Jurassic	Silt Stone		Poorly effective
4740 - 4742	"	Sand Stone		"
4742 - 4751	"	"		Fairly effective

0 50 100 150 200 md

Vertical not to Scale — Increase in Jointy Permeability than 2.0 mm are considered as caverns. Six types of voids are recognized in thin sections of limestones which are as follow :—

(i) Voids between or within mineral grains.

(ii) Voids between or within the skeletal remains of organisms.

(iii) Post incrustation voids.

(iv) Voids within stylolites.

(v) Voids because of leaching out skeletal remains or cementing material or any enclosing constituent.

(vi) Voids because of expansion along the open microjoints.

The figure given in this paper is jointy porosity, which is in fact a very minor amount of the jointy rocks total porosity and rarely attains 1 %. The formula for the calculation of jointy porosity is as follows :—

$$mj = \frac{b \ l}{S} \times 100 \text{ where}$$

'mj' represents jointy porosity %, 'b' is average width of open and bitumen filled joints in mm. 'l' is the total length of joints in mm. and 'S' is the area of rock section in mm^2.

Jointy porosity less than 0.1 % is considered as poor, 0.1 to 0.5 % as fair or moderate and greater than 0.5 % as high.

Jointy permeability.

Total permeability of jointy rocks is determined by the permeability of intergranular space and permeability of joints intersecting within rocks. In view of the fact that fissured reservoirs are invariably connected, even in highly compact and brittle rocks where intergranular permeability seldom exceeds 0.1 millidarcy and so the main permeability of such rocks is because of jointiness. Thus the determination of jointy permeability is important and is calculated from the following formula :—

$$K j = \frac{A.B \ b^3 \, l}{S} \text{ where}$$

'Kj' is jointy permeability in millidarcy, 'A' is constant for the same system of joints and its value is equal to 3.4×10^6 for one system of horizontal bedding joints, 2.28×10^6 for three reciprocally perpendicular systems of joints, 1.71×10^6 for two reciprocally perpendicular systems of vertical joints and also for chaotically arranged joints, 'B'=10 if permeability is calculated in millidarcy, 'b' is the average width of open and bitumen filled joints in mm, 'l' is the total length of joints in mm. and 'S' is the area of rock section in mm^2.

Rocks having jointy permeability less than 5 md. is considered as ineffective reservoir, 5 to 25 md. as poorly effective reservoir, 25 to 50 md. as fairly effective reservoir and greater than 50 as effective reservoir.

DISCUSSION

Jurassic clastics, Paleocene Khairabad limestone and Eocene Sakesar-Chorgali limestones have beds of oil and gas reservoir potentialities. So brief petrography and jointy parameters of these rocks are discussed.

Jurassic Variegated siltstone-sandstone are light to dark grey and whitish grey, medium hard to hard, moderately compact to compact, noncalcareous, somewhat fractured, argillaceous siltstone to silty fine grained sandstone with detrital constituents mainly quartz. Microjoints in sections show both the presence of horizontal and chaotic arrangement of joints, which are filled either by argillaceous or carbonaceous materials or both. Average width of open carbonaceous filled joints varies from 0.02 to 0.03 mm, volume density of joints from 90 to 108 per meter, jointy porosity from 0.11% to 0.21 and jointy permeability from 15.6 to 31.7 md. as shown in tables 1—3.

Palecene Khairabad limestone and Eocene Sakesar-Chorgali limestones are grey, compact, hard, fairly to highly fractured, pelitomorphic to microcrystalline, often dolomitic and micro-granular, pyritic, bituminous, fossilliferous, somewhat argillaceous with veins of recrystallized calcite. Microjoints are common which are generally filled either by calcite or with bitumen. Open joints and voids are also present in certain horizons. Average diameter of voids in thin sections is about 0.4 mm. Microjoints are mostly chaotically and horizontally arranged though vertical and inclined are also present. They show branchings, sometimes rough step like, curved, continuous to broken and in certain sections stylolitic sutures are also present. Average width of open or bitumen filled micro-joints in different sections varies from negligible to 0.04 mm, volume density of joints upto 295 per metre, jointy porosity upto 0.75% and jointy permeability upto 205 md. as shown in tables 1—3.

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A VIEW ON THE SURFACE AND SUB-SURFACE GEOLOGY OF THE DEGARI AREA

BY

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Abstract. *Original surface and sub-surface geological and structural maps of the Degari area are presented and an ever first attempt has been made to discuss the relationship between the surface and sub-surface geology. There appears to be direct relationship between the sub-surface micro-folds and the thinning of the coal seam.*

INTRODUCTION

P.M.D.C. Degari Mines are quire well-known for their coal production eversince the mines have been mechanised in 1962. During the phase of mechanisation, some geological work was done which served the purpose of the then management. In those davs coal working was shallow, at an incline depth of about 400 ft. from the mine mouth. After a period of 20-years, the coal working has reached at an incline depth of more than 2500 ft. from the mine mouth, therefore, necessity arised to prepare sub-surface geological maps in order to understand the downward trend of the coal seam.

In this regard fresh surface geological map was also prepared on the scale of 1 : 50,000, while sub-surface maps were prepared on the scale of 1″=100 ft. which were reduced up to the scale of 1″=400 ft. (Map-2) Emphasis of study was on the present behaviour of coal while previous data was also used for interpretation. It is the first attempt to discuss the relationship between the surface and sub-surface structural geology of the area.

LOCATION

Degari Mines are located at a distance of 56 Km all-weather road from Quetta via the Spezand railway junction (Map-1).

GENERAL GEOLOGY

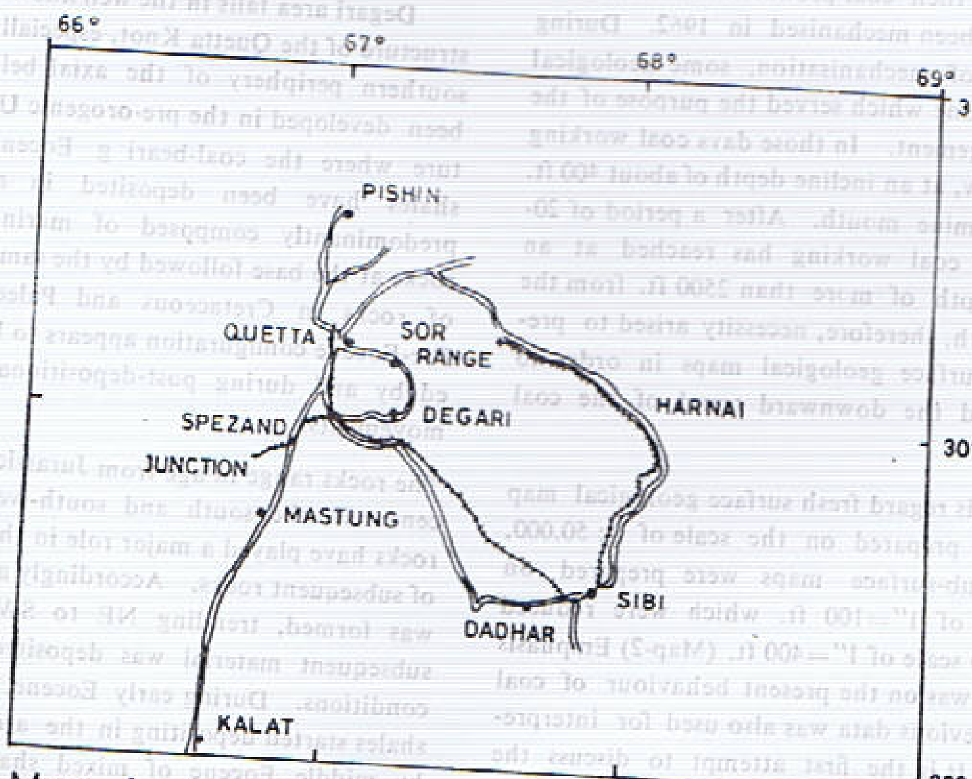
Degari area falls in the well known regional structure of the Quetta Knot, especially on the southern periphery of the axial belt. It has been developed in the pre-orogenic Urak structure where the coal-beari g Eocene Ghazij shales have been deposited in a syncline predominantly composed of marine Jurassic rocks at the base followed by the same sequence of rocks in Cretaceous and Paleocene age. Pre-Eocene configuration appears to be disturbed by and during post-depositional orogenic movements.

The rocks range in age from Jurassic to Oligocene. In the south and south-west, Jurassic rocks have played a major role in the formation of subsequent rocks. Accordingly a big trough was formed, trending NE to SW where the subsequent material was deposited in marine conditions. During early Eocene, Ghazij red shales started depositing in the area, followed by middle Eocene of mixed shale and sandstone. Then a sequence of grey to brown shales occurred with the late Eocene as a pure marine environment in the form of Kirthar limestone. In the axis of Pinakai syncline and in a little northern portion, Oligocene sandstone have deposited with intercalations of different shales.

Eocene Ghazij shales are commercially important as they have coal-bearing strata both in its early and middle stratigraphical column. Throughout Degari to Sor-Range, generally coal is extrated in early Eocene with the exception of Degari and a portion in its north where coal seams also occur in the middle part of the Ghazij shales.

The axis of the Pinakai syncline is a major structural drift from the main synclinal axis. The former syncline plunges towards north while the later mainly towards south-west. The whole area has been faulted.

In the western part of the Pinakai syncline, Degari coal-bearing strata forms a small structural unit which the author has termed as "Degari Anticlinal Plunge". This plunge is about two kilometer in length with the maximum width of about one kilometer. Its eastern limb is quite consistent as compared to its western limb which has undergone much faulting, from right-lateral to complete rotational faults. P.M.D.C. area mostly comprises the plunging nose structure as well as the eastern limo of the plunge, which dips generally at 45° to NE.



Map_1 Location map of the DEGARI area

UNDERGROUND GEOLOGY

The existing working mine plan has been shown in Map-2 where all the major inclines, skips, dips and levels have been shown. Previous to the preparation of this map, this map was over simplified, mainly serving the purpose of management and for various electrical and mechanical installations. However, the present author has improved this map so that some geological inter-pretation could be made possible by incorporating much of the previous unused data with some new entries and fresh survey of L-23 to L-26. As a result of this survey all significant micro-folds and areas where coal seam has thinned out has been marked on the map. Axes of the micro-folds have also been marked to make them conspicuous. In the north-east of the area, coal working was stopped by a major fault which has been named as "Degari Fault".

The Degari fault has been encountered right from the upper levels upto the level-24, where the normal coal seam has taken a turn at an angle of more than 70° to the normal coal seam which is generally north-south in its strike. The fault has been regarded as an upward thrust. As this fault is neither along true strike nor along at true dip, the present author feels that this fault has occurred at the beginning of a yet another fold which will be encountered in the unworked area further in the north-east. This fold will show some relationship with other micro-folds which have been identified and plotted on the map. The fault seems to be a hinge-fault.

From the Map-2, there seems some relationship between the micro-folding pattern, the Degari Fault and thinning of the coal seam. Generally speaking, in between the two micro-folds coal seam has thinned out and secondly, this thinning is expanding downward, a point which appears to be significant for further investigation for future mining activity.

In order to give some more detail picture regarding the micro-folds and thinning of the coal seam, some specific areas are described here ;

Adit-3

As is shown on Map-2, Adit-3 has reached up to the level of 1850 (L-25), about 2500 feet below from the mine mouth where it has encountered a micro-fold in its skip. In and around the vicinity of this fold, behaviour of coal seam is normal, being thickness of coal seam as 3ft except at the crest where coal seam has reached upto the thickness of 5ft. The coal seam dips at an angle of 42° to 45° towards NE, but the dip increases upto 52° at the floor of the bent. The axis of the micro-fold has been marked on the points which were encountered in the upper levels and longwals upto L-22 where it apparently appeared to be diminished. Influences of tectonic movements are more swere on floor rather than on the roof sandstone, as the roof showed mere broad undulations which are missing on the floor. The forces seemed to be acting from SE to NW directions.

From Dip-3, northernside, a level (L-25) starts as a normal level in between the sandstone with the thickness of coal seam as about 3 ft. Both roof and floor showed no unusual mark up to a distance of 200 ft. from the Dip. After that roof surface becomes nodular and fractures in sandstone filled with recrystallised limestone. The nodules are sandy in nature with slightly rugged surfaces. After 230 ft. the roof surface becomes more rich in nodules and recrystallised limestone showing an increasing trend towards north. While roof and floor maintaining their distances apart, clay starts appearing towards roof at a distance of 350 ft. where roof becomes irregular and pebbly in appearance with the simultaneous and correspondingly thinning of the coal seam. At 365 ft, coal seam becomes 2 ft. in thickness while it reduces upto 13" at a distance of 372 ft. from the Dip.

Adit-2

Just like the foregoing example, nature of coal seam thinning in Adit-2 at level-26 is also described here. At L-25, northernside from the Dip, sandstone of both roof and floor starts as normal beds with coal thickness of abou1 3 ft. After a distance of 38 ft. coal seam starts reducing its thickness at the development of clay. It reduces upto 4" in thickness in the longwall between L-25 and L-26, just at a 16 ft. rise from the level. As we proceed further, coal seam not only reduces its thickness, but it also splits up into two layers which have been measured as 10", the upper one, while the lower one as 13" The splitting of coal seam has been equally observed in the longwall both above and down.

CONCLUSION

Occurrence of anticlinal plunge structures on the western part of the Pinakai syncline is a unique phenomenon which is missing in the eastern part of the so-called Degari-Sor-Range anticline. Its strati-graphical and structural evolution calls for a separate study. Presence of micro-folds on the eastern limb of the Degari plunge seem to have some relationship with the thinning of coal seam as encountered in the underground coal workings at the P.M.D.C. collieries. Axes of these micro-folds are nearly parallel to each other which make an angle of 60° to the normal strike. From surface geology, it appears that these micro-foldings have been developed by movements which acted from SE to NW directions generated by a block situated in the SE adjoining area of the P.M.D C. known as the area of M/S Kalat Co. This block is a very small anticlinal plunge, faulted both at its east and west. As the clay has beed deposited in between the mirco-folds, an obvious interpretation is that streams washed the coal in between the micro-folds with the deposition of clay, silty clay along their water courses. The downward expansion of clay deposits may be taken seriously and further area for coal may be proved by drilling.

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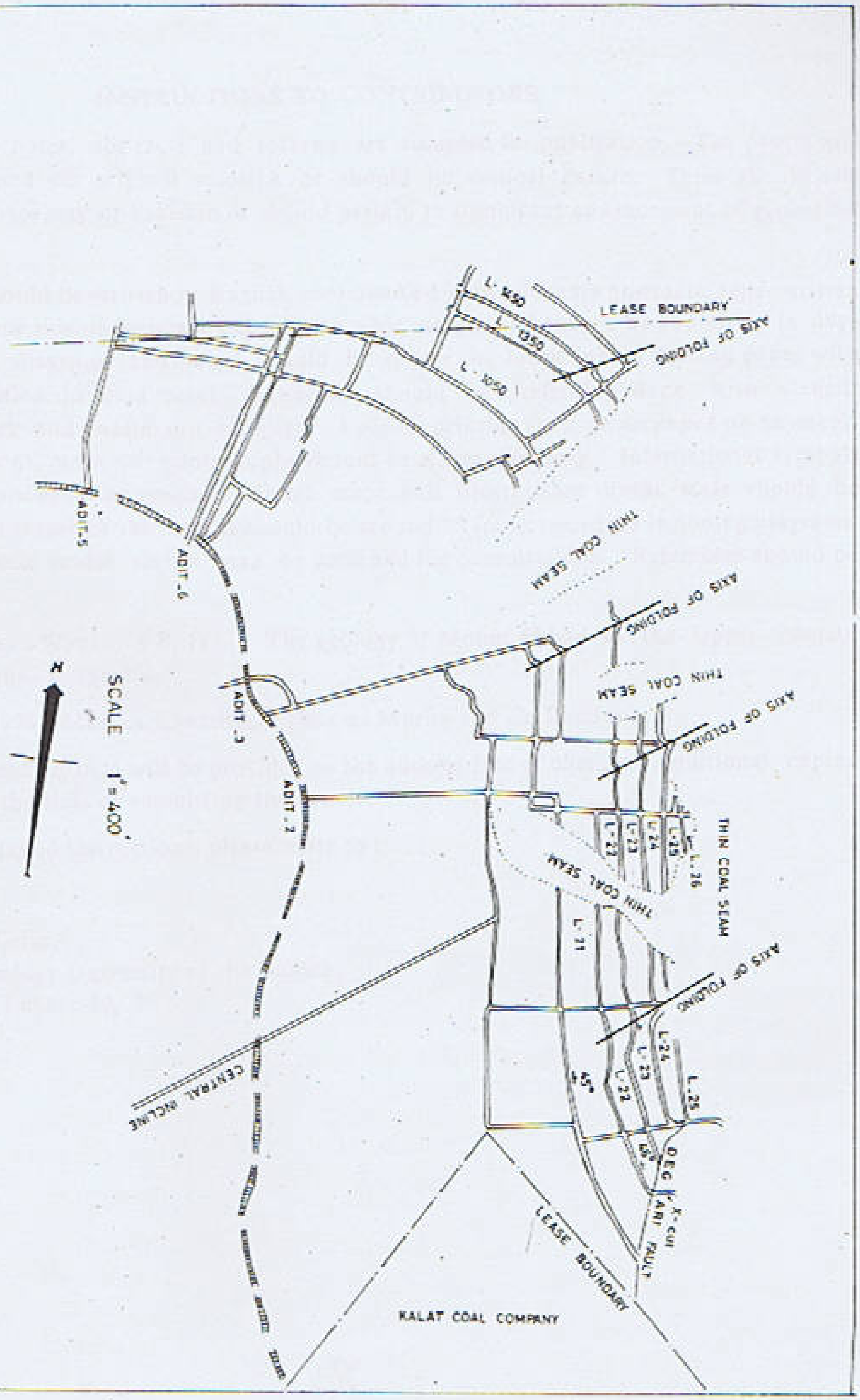

Map - 2 P.M.D.C. COLLIERIES DEGARI

UNDERGROUND WORKING PLAN SHOWING MICRO FOLDS & THEIR BEHAVIOUR ON THINNING THE COAL SEAM

Prepared by, Iftikhar A. Malik 7.1.82