Bull. Soc. belge Géol., Paléont., Hydrol.	T. 80	fasc. 3-4	pp. 133-144	Bruxelles 1971
Bull. Belg. Ver. Geol., Paleont., Hydrol.	V. 80	deel 3-4	blz. 133-144	Brussel 1971

TRACE-ELEMENT GEOCHEMISTRY AND PETROLOGY OF THE BADAMU LIMESTONE (Early Toarcian to Middle Bajocian), BABNIZU AREA, KERMAN — IRAN

ASSAD IRANPANAH

Department of Geology
The University of Tehran

SUMMARY. The geochemical and petrological analyses were made on 70 selected samples from Badamu Limestons in Babnizu area, Kerman. The environment of deposition of the Badamu Limestone was shown to be near-shore marine.

The Cu and Pb content of the samples increases progressively to the eastern, deeper marine environment. Zn culminates in low energy zones where the immature clastic sediments occur. There is direct correlation between the distribution of carbonates such as high-Mg calcite and dolomite and the distribution of Cu and Pb.

There is a significant positive correlation in the distribution of Cu and Zn as shown by the calculation of the rank correlation and the graphic method. The calculations and graphs also show that there is a negative correlation for the distribution of Cu and Pb; and Pb and Zn (with some local exceptions), with a level of confidence of about 99 percent.

The Mo content is so small that no systematic trend can be discerned.

RÉSUMÉ. Septante échantillons sélectionnés de calcaire de Badamu, dans la région de Babnizu, Kerman, firent soumis à l'analyse géochimique et pétrologique. Les conditions de déposition indiquent un milieu marin prélittoral.

La teneur en Cu et Pb des échantillons augmente graduellement vers l'Est, direction qui correspond à un milieu marin plus profond. Le Zn est particulièrement abondant dans les zones moins agitées, riches en sédiments clastiques jeunes. Il existe une correlation directe entre la distribution des carbonates tels la calcite riche en Mg et la dolomie d'une part, et la distribution du Cu et du Pb.

Le calcul de la *Rank-correlation* et la méthode graphique ont permis de mettre en relief une correlation positive significative entre les distributions de Cu et Zn; inversement une corrélation négative entre Cu et Pb d'une part, Pb et Zn (à quelques exceptions près) de l'autre — ceci avec un degré de confiance de quelque 99 %.

La teneur en Mo est trop faible pour qu'aucun gradient systématique puisse être détecté.

Introduction

The area of study is located in 55-56 kilometers NNW of Kerman and 65-70 kilometers SE of the Tangal village. The length of the belt under study is about 11 km. (Fig. 1) which occupies the southern edge of the Zarand Trough.

To ascertain the framework in which the sediments of Badamu Limestone were deposited, the general petrological and geochemical studies of these rocks were made in Babnizu area, Kerman. The bulk mineralogical composition of the Badamu Limestone was determined by means of a petrographic microscope and an X-ray diffractometer. The microscopic studies show that the Badamu Limestone in Babnizu area has gradation in detrital quartz and clay minerals with authigenic calcite and dolomite.

Samples from sections A through T were studied for their bulk calcite and quartz con-

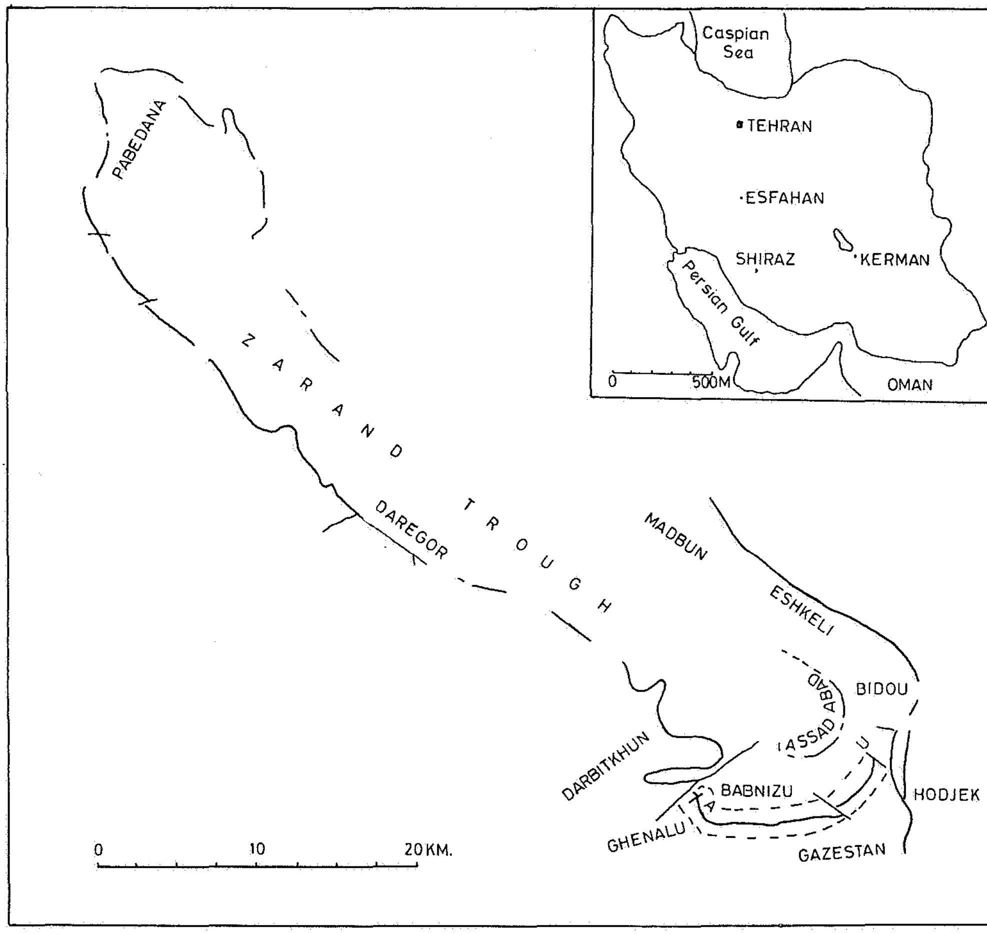

Fig. 1. Index map showing the outcrop of Badamu Formation in Zarand trough and the study area.

tent by means of an X-ray diffractometer. Samples from sections A through U were analyzed for their trace element contents by means of Atomic Absorption.

The highest calcite site occurs in the sections that are measured in the eastern part of the area (fig. 2 and 3); but the highest peak of quartz belongs to the western sections.

Stratigraphy

The geochemical studies were only made on the marking horizon of limestones in Babnizu area. Previous investigators called this unit "Cephalopod Limestones" or Babnizu Formation (Huber and Stocklin, 1954).

The thickness of the Badamu Limestones in Babnizu area increases from east to west. Volumetric estimation of the clastic contents of the Badamu Limestone shows that they vary in thickness from east to west due to the presence or absence of the patches of detrital grains. Patches of greenish-gray siltstones and argillites occur most predominantly in the western section. Patches with a thickness of more than 50 meters are common. The distribution of the detrital grains was apparently influenced by the proximity of the shore which most likely existed toward the north and northwest.

The rock unit is overlained by a coal-bearing horizon "D" (Dogger), in Kerman region. This horizon is represented by different

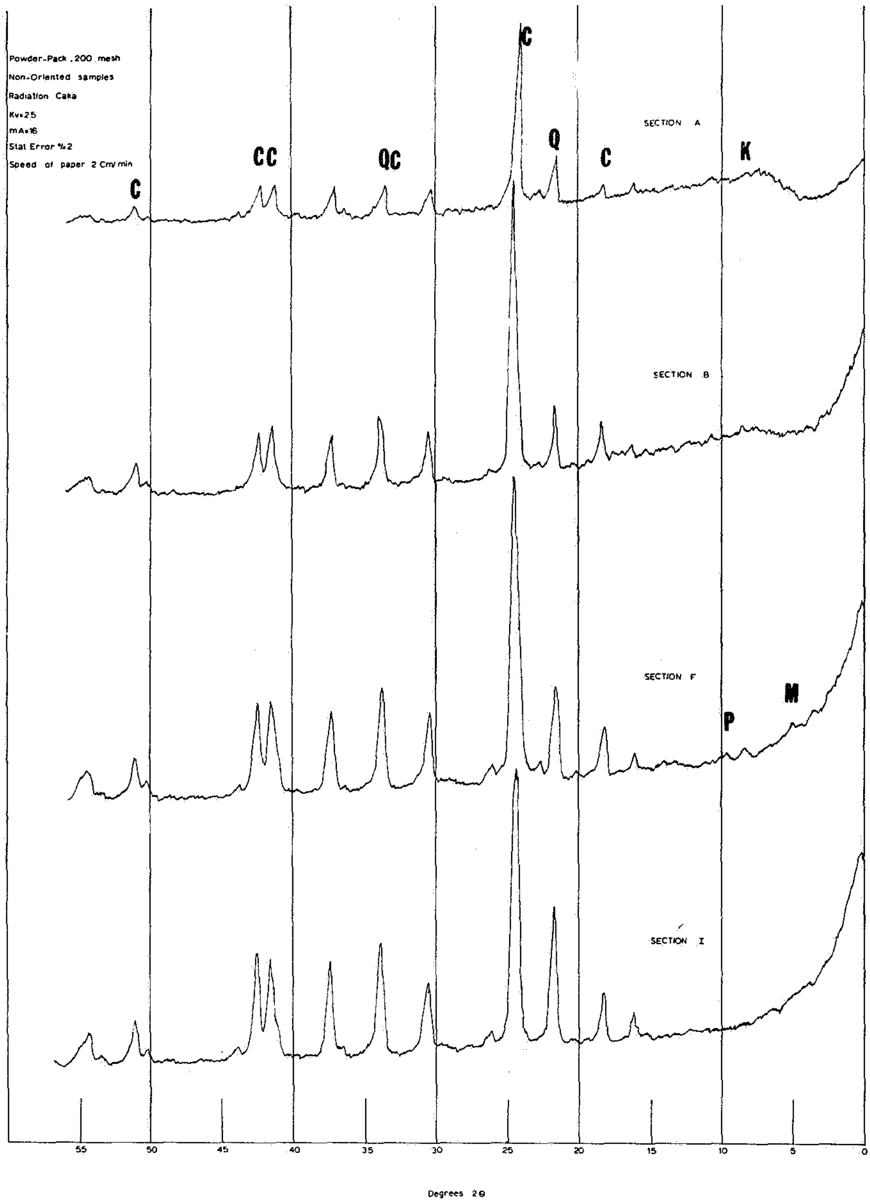

Fig. 2. X-ray diffractometer scans of selected samples from Badamu Formation, Bab-Nizu Area, Kerman.

C = Calcite
Q = Quartz
P = Plagioclase Feldspars
K = Kaolinite
M = Micaceous clay minerals (Montmorillonite)

fine-grained sandstones with subordinate interlayers of fine siltstones.

Ammonites, belemnites, and lamellibranch mollusc remains were collected in various sections throughout the study area. According to Emami's determination (1968), the Badamu Limestone was considered to be of a late Early Toarcian to Middle Bajocian age. This determination was confirmed by the study undertaken by REPMAN and CHEPIKORA (personal communication), on the pelecypoda content of the formation.

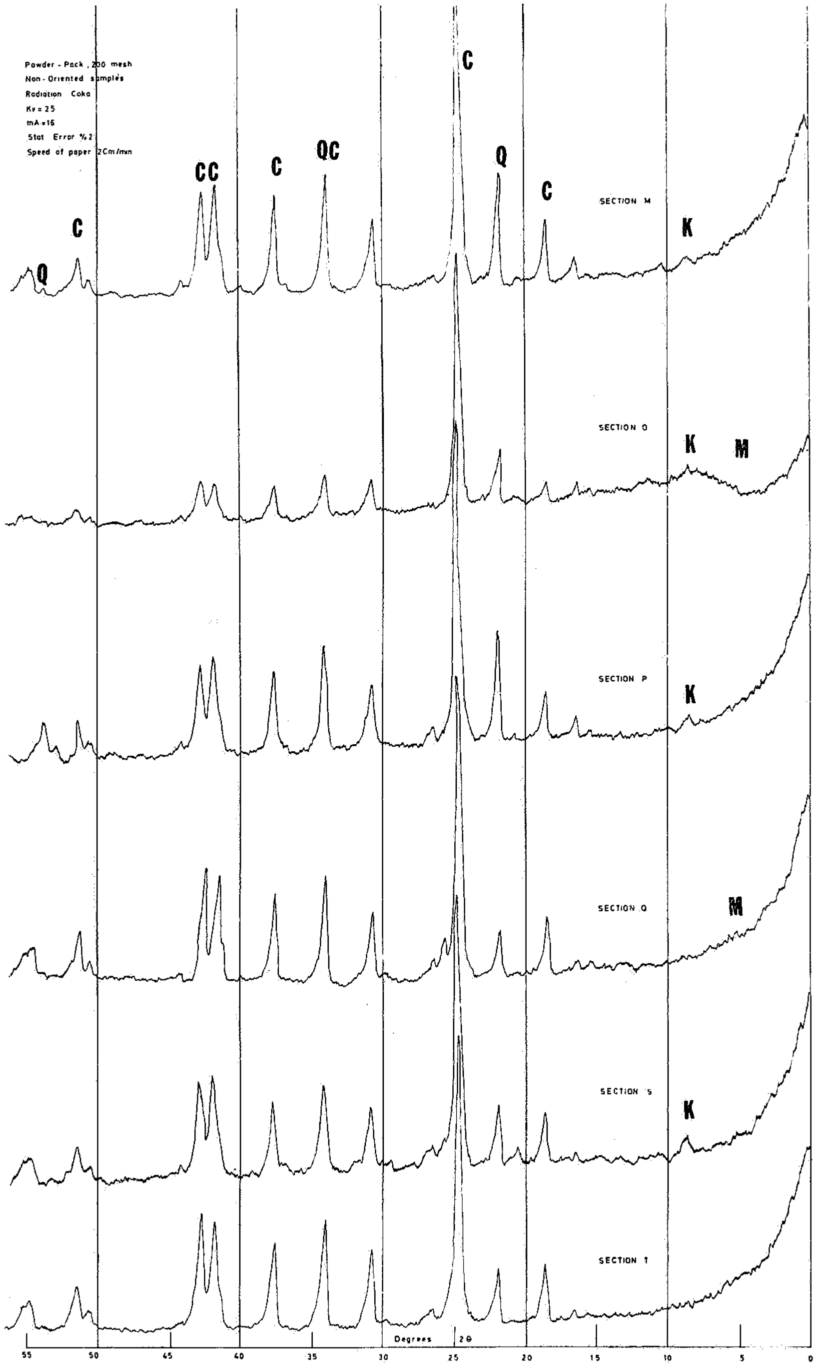

Fig. 3. X-ray diffractometer scans of selected samples from Badamu Formation, Bab-Nizu Area, Kerman.

Petrology

The sedimentary section consists of interbedded limestones which are generally graded into dolomitic limestones and delomites to the east, and marly limestones, siltstones and sandstones with minor conglomerates to the west. The sequence is highly fossiliferous in calcareous suite.

The petrological investigation of the Badamu Limestone shows that they are composed of calcarenites, calcirudites containing micro-and-macro fauna, with microscopic clay-galls and some organic matter. Alternating with these, there are siltsones, sandstones with some marls and few conglomerates interbedded with limestones. Dolarenites occur predominantly in the eastern part of the area.

Except for the argillaceous beds which are common in the central part of the area, the rest of the rock unit is well cemented with calcite, some dolomite, and silica. The shaly units contain appreciable amounts of silt-sized, detrital quartz and are moderately — to — poorly indurated.

GEOCHEMISTRY

Procedure

The samples were disaggregated and split into two equal fractions. One fraction was stored and the other was pulverized to − 120 mesh. An aliquot of each pulverized sample (− 200 mesh) was removed for X-ray diffraction analysis.

The method used for determination of metal contents was that of B.R.G.M. For decomposition, 1.25 gm. of each sample was transfered into 50 ml calibrated test tubes, and 2.5 ml of concentrated HCl and 2.5 ml concentrated HNO3 (pure grade reagents) were added. Each series of about 85 tubes (70 samples with 15 duplicates) was placed in a water bath for a period of one hour. Distilled water was added to approximately 50 ml and the diluted solution was left in the water bath for another hour. The tubes were then cooled to room temperature, the volumes brought to 50 ml with distilled water, and after shaking, filtered into dry bottles.

The metal contents in the acidified solution were then determined by atomic absorption spectroscopy with a model 3030 Perkin Elmer. The absorbancies were measured against a blank solution of distilled water and were directly converted into p.p.m. from a table deduced from a calibration curve made by standard solutions.

Discussion of results

Recent work in trace element geochemistry (Turekian, 1963b; Ahrens, 1965, 1966; Curtis, 1964; Taylor, 1964; Burns and Fyfe, 1966a; Nockolds, 1966) shows that with a knowledge of the conditions under which the primary magnetic minerals were formed, one can interpret and predict element distribution in the rock. It is suggested in this paper that one can predict the trace element content of a rock only by a complete mineral analysis which includes careful consideration of the following factors: homogeneity, phase equilibria, thermodynamic factors, ionic radii, electronegativity, melting point, and heat of formation.

Accepting the correlation between primary magnetic minerals and their trace element content, it is possible to interpret and predict the mineralogy as well as the petrology of the sources of the sedimentary rocks by trace element analysis.

A total of 70 samples were selected for analysis for their trace element content along the east-west section, from Babnizu area, Kerman. The results are summarized in Table 1. First, spectrographical scans were made for the elements that are most important in the interpretation of the sedimentary environments. Except for Pb, Cu, Zn and some Mo most of the elements occur in very small amounts. Pb, Cu, Zn, and Mo were analysed by means of atomic absorption.

The mean distribution of the trace elements in all sections was plotted and compared to the

TABLE 1. *Determination of Pb, Zn, Cu, Mo in 70 following samples.*

Lab. No.	Field No.	p.p.m. Pb	p.p.m. Zn	p.p.m. Cu	p.p.m. Mo
Sa-448	8742-19 A	60	16	12	1
» 449	8743-18 A	49	28	9	1
» 450	8744-16 Aa	26	44	14	1
» 451	8745-16 Ad	43	36	14	1
» 452	8746-15 A	57	25	9	2
» 453	8747-13 A	50	19	11	2
» 454	8748-12 A	41	81	22	2
» 455	8749-11 A_1	40	30	17	2
» 456	8750- 9 A	56	24	10	2
» 457	8751- 9 A_2	57	18	10	2
» 458	8752-36 B	110	25	11	2
» 459	8753-29 B	33	64	14	2
» 460	8754-24 B	33	50	19	2
» 461	8755-17 B	26	76	21	2
» 462	8756-10 B	43	15	9	2
» 463	8757- 8 B	34	22	12	2
» 464	8758- 2 B	40	57	15	1
» 465	8759-39 C	20	81	23	1
» 466	8760-33 C	52	60	14	2
» 467	8761-30 C	22	105	27	1
» 468	8762-17 C	24	82	24	2
» 469	8763-15 C	34	26	10	2
» 470	8764-13 C	41	22	13	2
» 471	8765-12 C	104	24	11	2
» 472	8766- 5 C	41	19	9	2
» 473	8767- 2 C	46	22	10	1
» 474	8768-41 D	20	110	21	1
» 475	8769-38 D	37	84	32	1
» 476	8770-35 D	68	21	13	2
» 477	8771-31 D	40	28	9	2
» 478	8772-29 D	24	64	14	2
» 479	8773-28 D	24	70	26	2
» 480	8774-24 D	31	51	19	2
» 481	8775-15 D	50	24	12	2
» 482	8776-10 D	29	63	9	2
» 483	8777- 7 D	39	17	8	2
» 484	8778- 4 D	36	70	21	2
» 485	8779- 1 D	69	18	9	2
» 486	8780-31 F	48	94	9	2
» 487	8781-23 F	21	89	22	2
» 488	8782-17 F	31	36	16	1
» 489	8783- 8 F	34	15	8	2
» 490	8784- 4 F	37	11	8	1
» 491	8785-24 I	60	14	10	2
» 492	8786-13 I	26	91	15	2
» 493	8787-11 I	44	21	8	2
» 494	8788- 9 I	29	31	8	2

TABLE 1 (continued).

Lab. No.	Field No.	p.p.m. Pb	p.p.m. Zn	p.p.m. Cu	p.p.m. Mo
» 495	8789- 4 I	43	17	8	2
» 496	8790-18 M	57	78	9	2
» 497	8791-14 M	57	23	10	2
» 498	8792-11 M	26	96	19	2
» 499	8793- 5 M	40	21	8	2
» 500	8794- 3 M	36	19	9	2
» 501	8795-16 O	33	21	10	1
» 502	8796-10 O	31	23	16	2
» 503	8797- 6 O	41	21	10	1
» 504	8798- 2 O	47	10	11	2
» 505	8799-12 Q	57	12	11	2
» 506	8800- 9 Q	53	16	10	2
» 507	8801- 6 Q	52	13	12	2
» 508	8802- 3 Q	43	25	10	1
» 509	8803-11 S	65	9	8	2
» 510	8804-10 S	47	27	7	2
» 511	8805- 5 S	52	18	9	2
» 512	8806- 1 S	63	33	9	2
» 513	8807- 7 T	46	17	10	2
» 514	8808- 5 T	49	16	9	1
» 515	8809- 3 T	36	19	9	1
» 516	8810- 1 T	69	28	9	1
» 517	8811- 4 U	34	13	8	1

average distribution of the same elements in standard shales and carbonates. The diagram shows that none of the samples have a Zn content usually found in shales. The average Zn content in standard shales is about 95 p.p.m. The trace contents of the Badamu Limestone is closely similar to that of the marine carbonates (Fig. 4).

The amount of Zn decreases to the east as does the clay content of the samples, but Pb content increases more or less progressively toward the more marine environment. (Figs. 4 and 8).

The Zn and Cu contents of the samples are correlated in Fig. 5. It shows that there is a positive correlation between two elements. Correlations between Pb and Cu, and Pb and Zn are illustrated in Figs. 6 and 7. They show a parabolic correlation throughout the area.

Statistical calculation for trace element correlations were made by using the following equation:

$$r = 1 - \frac{6 \Sigma D^2}{N (N^2 - 1)} \qquad (1)$$

in which, r is the rank correlation, D is the difference between R_1 and R_2; and N is the number of the samples analyzed. The calculation was made for ungrouped data; Eq. (1).

The rank correlation of Pb and Zn ($r = - 0.625$) indicates that there is a significant negative correlation in the distribution of these elements. Examination of figure 6 also shows the same result. Calculation of the rank correlation for the Cu and Zn distribution shows that there is a positive correlation between the two elements ($r = 0.547$). The level of confidence of correlation is about 99 percent. This is characteristic of the sandy argillaceous calcarenites, as we have in the

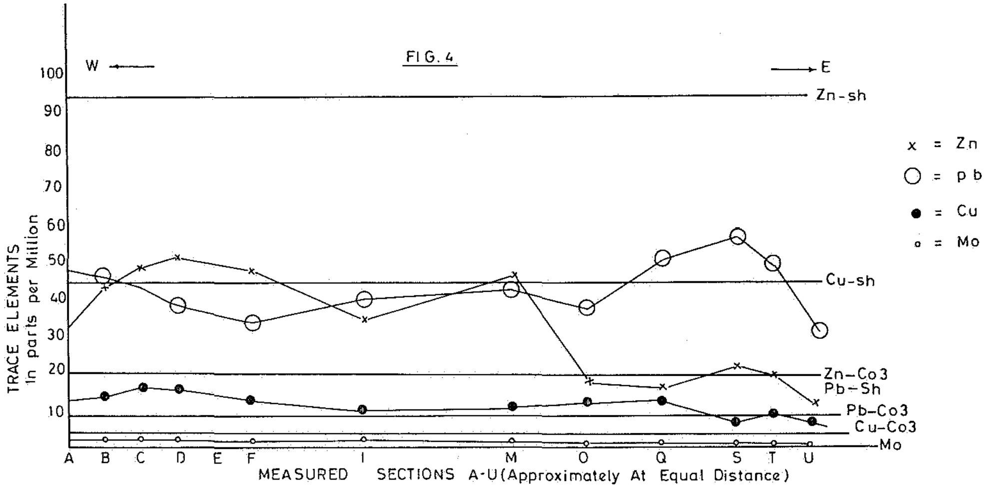

Fig. 4. Measured sections A-U (Approximately at equal distance) versus trace elements in p.p.m.

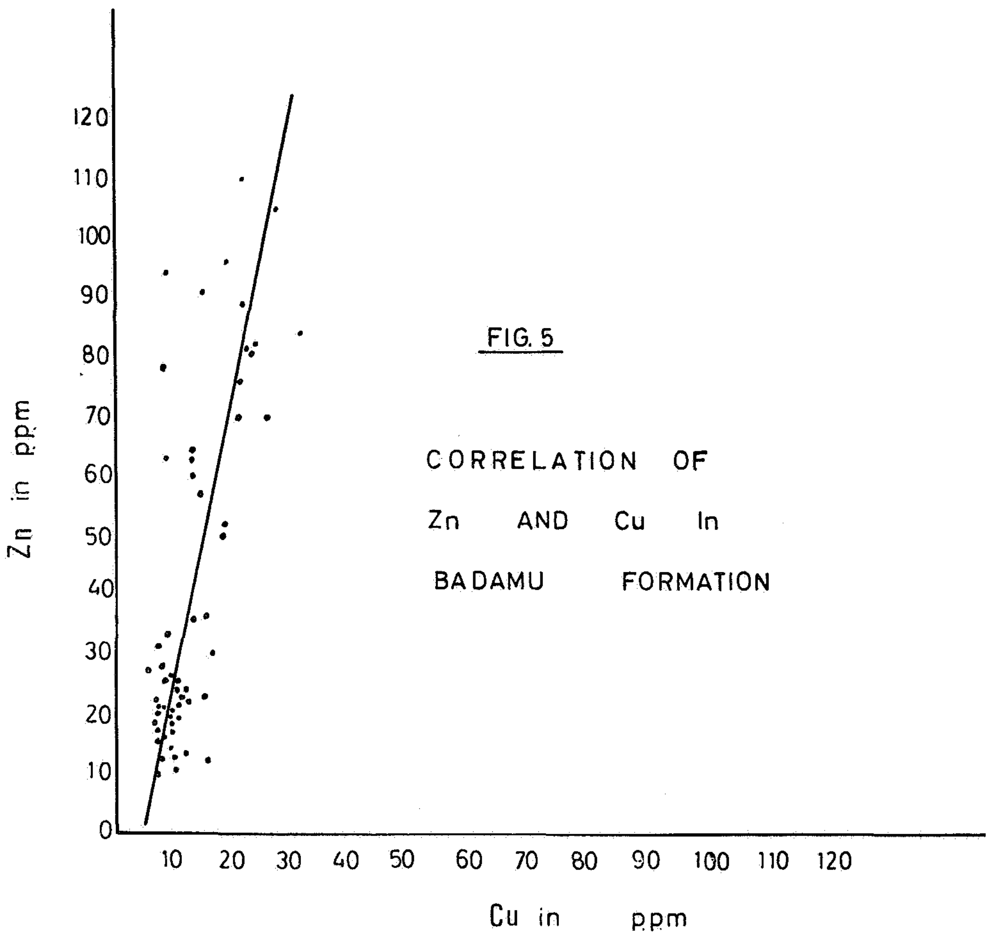

Fig. 5. Correlation of Zn and Cu in Badamu Formation.

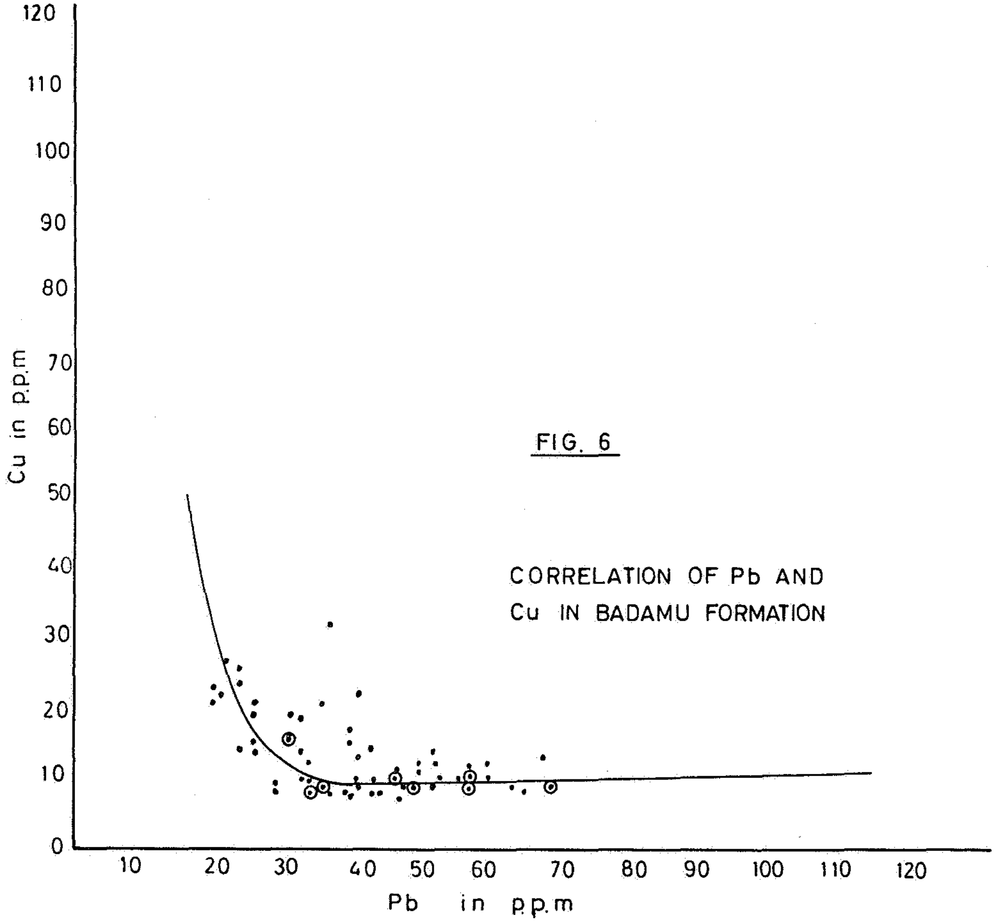

Fig. 6. Correlation of Pb and Cu in Badamu Formation.

Badamu Limestone, which were probably deposited in a near-shore marine environment. The same result was obtained from the correlation of Cu and Zn by graphic method (Fig. 5).

There is a significant negative correlation between Cu and Pb distribution, at a level of 99 % confidence (Fig. 6).

The distribution of each trace element was plotted against the thickness of the measured sections (Fig. 8). The results show that there is a positive correlation between Zn and the argillaceous limestones. Cu and Pb occur predominantly in calcarenites and dolarenites, but Zn is approximately more predominant in the sandy argillaceous calcarenites. Mo occurs to be more or less constant throughout the sections. Examination of the diagrams (Fig. 8), shows that in some localities there is an exceptional positive local correlation between Pb and Zn (Pb content is highest where the Zn content is lowest).

Conclusions

(1) It is possible to identify the environments of deposition of the sedimentary rocks studied (near-shore marine) on the basis of almost any single one of the chemical or mineralogical parameters measured.

(2) Contents of Cu and Pb more or less progressively increase toward the more marine environmental condition. Their distribution in

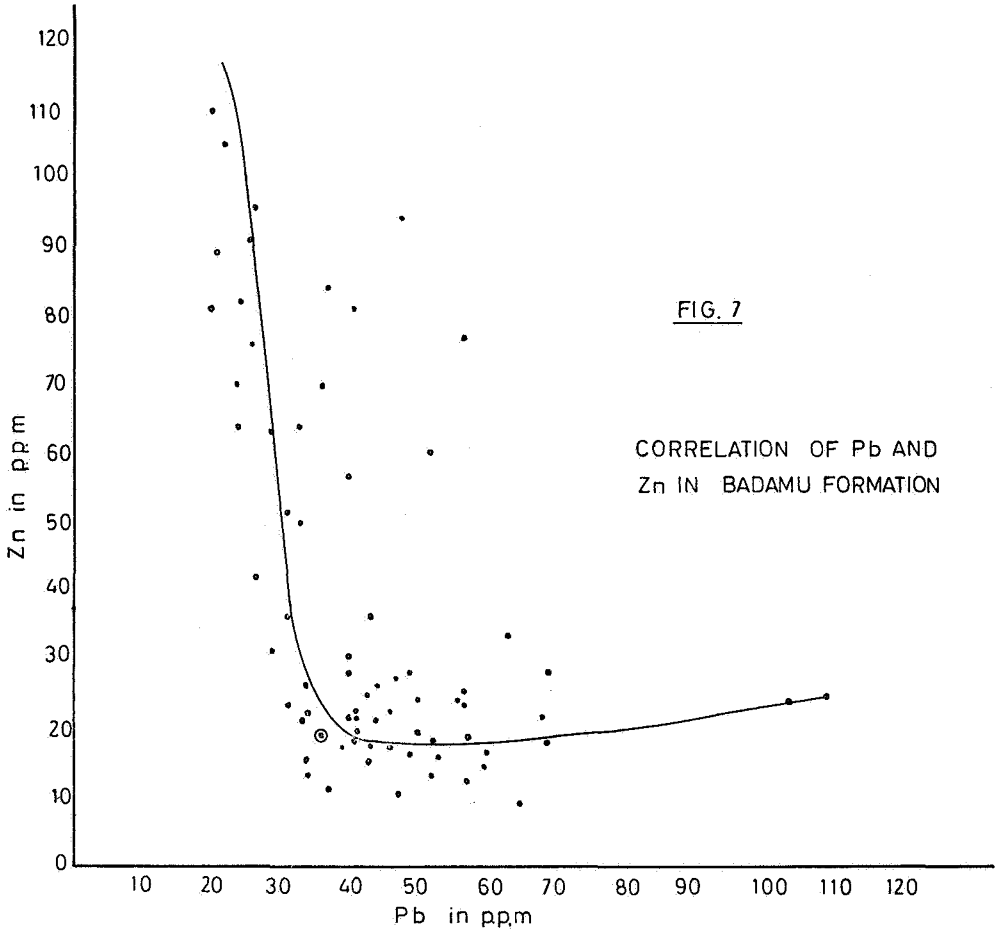

Fig. 7. Correlation of Pb and Zn in Badamu Formation.

Badamu Limestone is primarily related to the increase of high-Mg calcite and dolomite throughout the section.

(3) Zn culminates in exceptionally low energy zones of the environment of the Badamu Limestone where the locally enriched clayey calcarenites occur. In these zones, the carbonate content exerts a discernable secondary effect because of the abundance of the fine-grained silts and clay minerals. The Zn concentration seems to be very closely dependent on the clay content.

(4) The calculation of the rank correlation for the analyzed data shows that there is a significant positive correlation between the distribution of Cu and Zn, with a confidence of about 99 percent.

There is a negative correlation in the distribution of Cu and Pb with some local exceptions, as shown by the calculation of rank correlation and graphic correlation.

A negative correlation is also present between Pb and Zn with a level of confidence of about 99 percent.

(5) The Mo content is so small that no systematic trend in their distribution can be discerned.

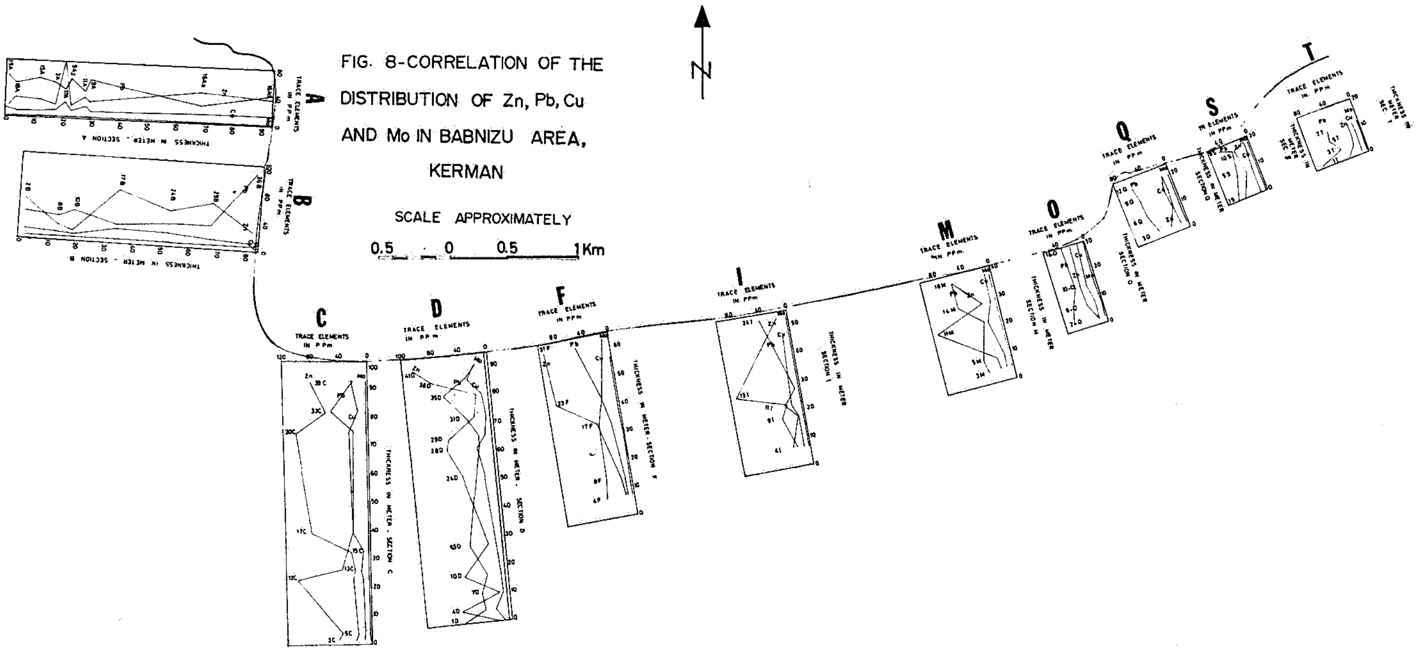

Fig. 8. Correlation of the distribution of Zn, Pb, Cu and Mo in Babnizu area, Kerman.

Acknowledgments

The writer wishes to extend his appreciation to the assistance of the following persons; Mr. M. REZVANINAZHAD for making the samples available, Misters A. TADAYON and G. VOSSOUGHIZADEH for geochemical analyses, and Mr. M. SADRZADEH for X-ray assisting throughout this investigation.

REFERENCES

AHRENS, L.H., 1965. Distribution of the elements in our planet. McGraw-Hill, New York, N.Y., 106 pp.

AHRENS, L.H., 1966. The chemical bond and the geochemical distribution of the elements. *Chem. Brit.*, **2**: 14-19.

BURNS, R.G. and FYFE, W.S., 1966a. Distribution of elements in geological processes. *Chem. Geol.*, **1**: 49-56.

CURTIS, C.D., 1964. Application of the crystal-field theory to the inclusion of trace transition elements in minerals during magmatic crystallization. *Geochim. Cosmochim. Acta*, **28**: 389-402.

HUBER, H., and STÖCKLIN, J., 1954. Hodjeck coal survey: *Natn. Iran. Oil Co. Rept.* 116, 65 pp. (Unpublished), Tehran.

NOCKOLDS, S.R., 1966. The behaviour of some elements during fractional crystallization of magma. *Geochim. Cosmochim. Acta*, **30**: 267-278.

REPMAN, E.A. and CHEPIKORA, S.H., 1970 Personal communication.

SEYED-EMAMI, K., 1968. The Badamu Formation Northwest of Kerman. *Geol. Soc. Iran*, Note No. 45, 29 pp.

TAYLOR, S.R., 1964. The application of trace element data to problems in petrology. *Phys. Chem. Earth*, **6**: 133-214.

TUREKIAN, K.K., 1963b. The use of trace element geochemistry in solving geologic problems. *In:* Shaw, D.M. (Editor), *Studies in Analytical Geochemistry*. Univ. Toronto Press, Ont., 3-24.

Communication presented on the 16th of March 1971.