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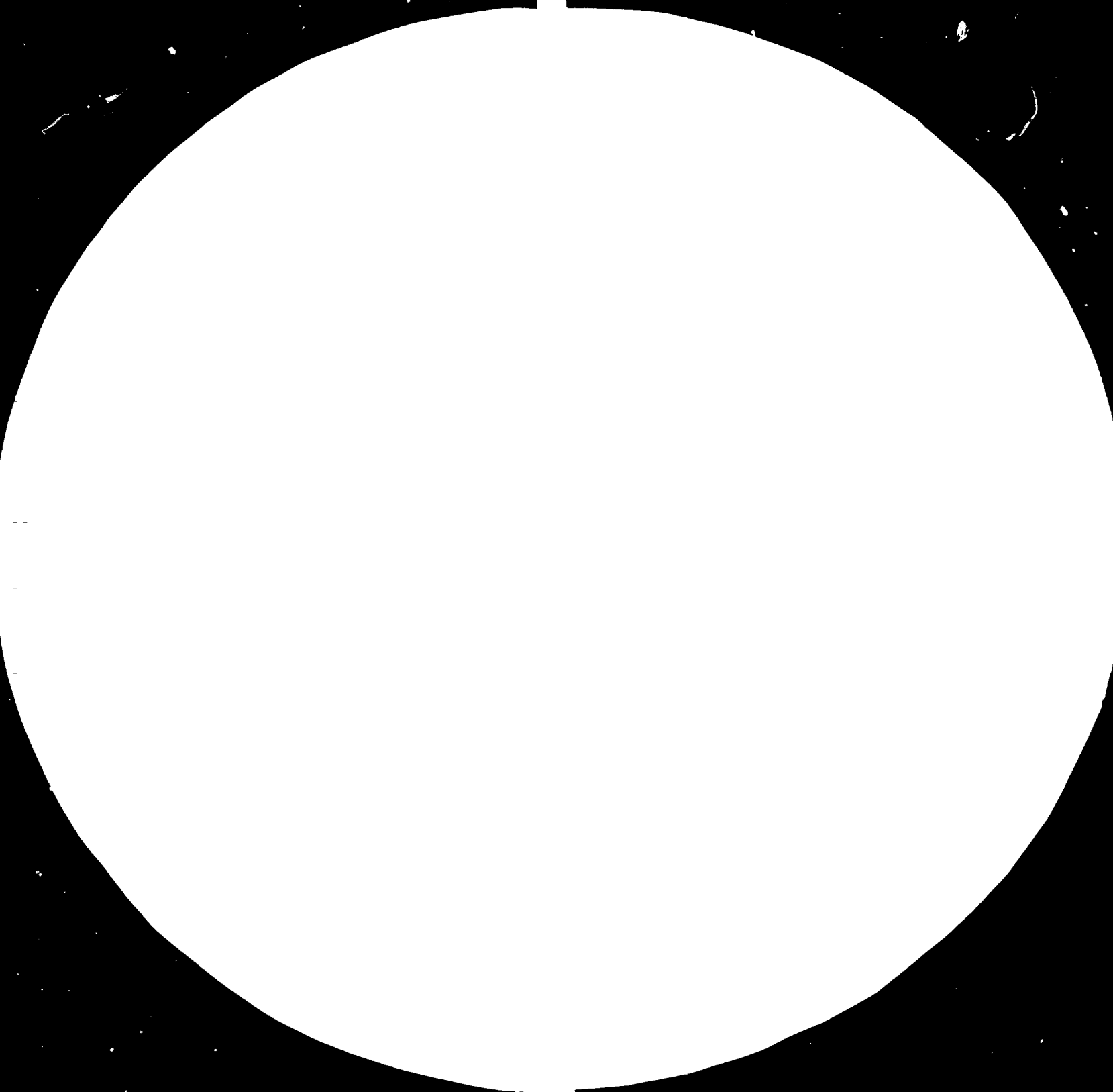

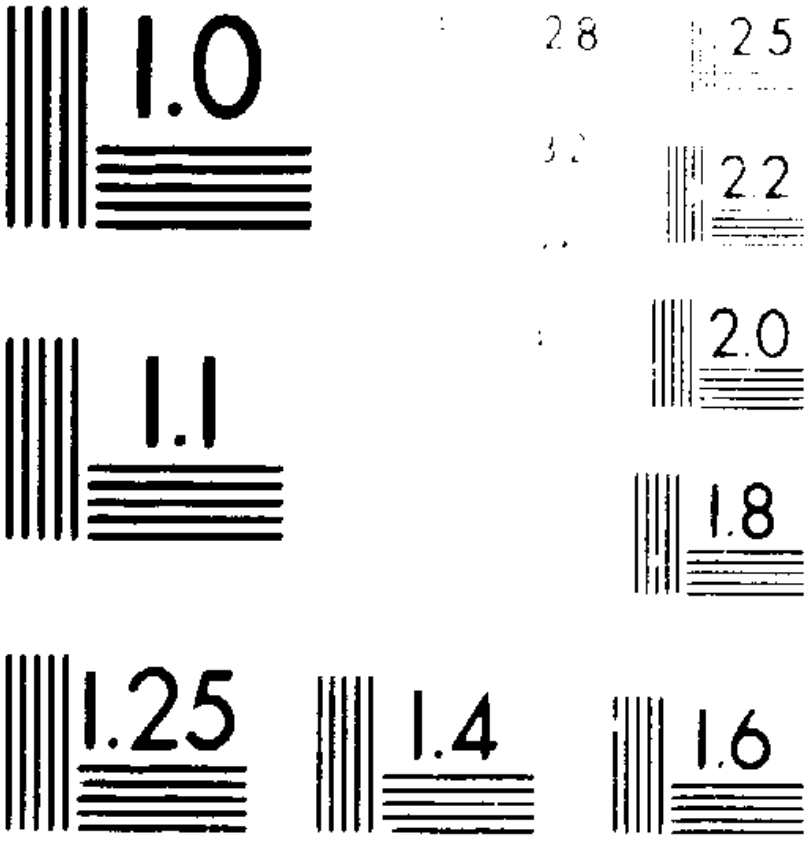
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DEVELOPMENT OF A BASIC INDUSTRY FOR THE PRODUCTION OF ALUMINA FROM INDIGENOUS ALUMINIFEROUS ORES SUCH AS ALUNITE AND BAUXITE

DP/IRA/84/002/11-03A

ISLAMIC REPUBLIC OF IRAN

Technical report: Bauxite and alunite mineral commodity

Prepared for the Government of Islamic Rep. of Iran
by the United Nations Industrial Development Organization,
acting as executing agency for the United Nations Development Programme

Based on the work of:

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United Nations Industrial Development Organization

Vienna

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A B S T R A C T

In connection with the Project of "Development of a basic industry for the production of alumina from indigenous aluminiferous ores such as alunite and bauxite" /DP/IRA/84/002/11-03A/ two consultants visited the bauxite and alunite deposits of Iran /13.08.1984 - 12.09.1984/.

Undertaking field trips and based on discussions with Iranian companies and experts consultants' main conclusions and recommendations are as follows:

- large resources of alunite are prospected in NW Iran having about 340 million tons of estimated resources,
- diaspore-chamositic bauxite deposits in the Elburz Mountains are promising both for an economic size and type for mining and for an economic alumina production by modern Bayer technology. The estimated resources are more than 64 million tons,
- detailed works are recommended for completion both of alunite and bauxite prospection and evaluation programmes of ALUMIRAN including the necessary investigations and analysis of characteristic bauxite and alunite samples.

I. INTRODUCTION

Iran's aluminium consumption is about 12o.ooo tons per year, of which only one third is produced locally in the Arak smelter from imported alumina. Given the Government's plans, Iran's alumina requirements are likely to reach 6oo.ooo to 8oo.ooo tons/year in the early 199oies, requiring foreign exchange expenditures of about US dollars 2oo million for its import. The Government, therefore, has given the utmost urgency to the production of alumina within the country, out of its alunite and/or bauxite resources.

Iran has very large prospected deposits of alunite to the north-western region of the country, the total estimated resource of which is about 34o million tons, with an average alunite content of more than 35 %.

The result of the reconnaissance and prospecting works carried out during the past by ALUMIRAN in the Elburz Mountains was the identification of some prospective bauxite deposits. The total estimated R-3 resources /according to the UN Classification of Mineral Resources, see Ref. list No. 15/ of these deposits are about 64 million tons. Sophisticated mineralogical and alumina technological tests proved, that an economic technology can be developed for this type of bauxite.

To reach the objectives mentioned above, the Ministry of Mines and Metals of Iran has set up an "Aluminium Raw Materials Programme" /ARMP/ with plans for:

- continuation of the necessary geological exploration and mining works for producing the samples necessary for detailed testings and analysis
- the establishment of a complex testing laboratory for aluminiferous ores
- undertaking Prefeasibility and Feasibility Studies both for alunite and bauxite based alumina production till the end of 1986.

These plans are summarized in time tables as follows.

Time table for bauxite and alunite exploration /by ARMP/

Bauxite

/x= quarterof year/

	1984	1985	1986	1987	1988	1989	1990	1991	1992
1 Exploration of 3 areas	xx	xxxx							
2 Exploration of Zagros area			xxxx	xx					
3 Selection of supplies of technology and discussion		xxxx	xx						
4 Pilot testing of various bauxite qualities			xx						
5 Feasibility Study Mining			xxx						
6 Feasibility Study for Alumina Plant 300.000 /600.000/ tpy				xxxx					
7 Financing and /parallel/ engineering					xx				
8 Construction of Alumina Plant					xx	xxxx	xxxx	xxxx	
9 Development bauxite mine and production /1 million tpy/					xx	xxxx	xxxx	xxxx	xxxx
10 Start production alumina 300.000 tpy									xxxx

Alunite

1 Elaboration of establishment of exploration program and execution of work	x	x							
2 Selection of characteristic samples and sending for lab. testing to VAMI; mining feasibility study	xx								
3 Preparation of representative sample /VAMI/		xx							
4 Elaboration of establishment of technology and report on results from No.3.		xx	x						
5 Pilot scale test /basic eng./		xx							
6 Feasibility Study for alumina			xxxx						
7 Financing and engineering			x	xx					
8 Beginning of construction 1st line 100.000 t alumina py				xx	xxxx	xxxx			
9 Start production of alumina							x		
10 Construction 2nd line of 100.000 t alumina py							xx	xxxx	xx

UNDP and UNIDO are in cooperation with the Iranian Government by sending experts and by financing the preparation of a complex laboratory mentioned above and by financing the sampling and testing works finally required for Feasibility Studies.

Based on experiences gained during field trips and consultations with Iranian experts and by evaluation of earlier investigation reports both on bauxite and alunite resources the present Report is giving recommendations for further necessary works to be done.

II. BAUXITE RESOURCES

A. Earlier investigations

Present Report does not deal in details with the earlier investigations for bauxite or alunite in Iran, consequently the following short review does not want to be a complete and detailed historical evaluation.

Bauxite in Iran is first mentioned by WALTHER and KÜRSTEN /16, in 1958/ of the West German Geological Survey, as diasporite of Bulbuln near Kerman. In 1966 this area was investigated by SABOT /11/. A sample collected by Sabot was the first Iranian bauxite tested by X-ray phase analyses by BÁRDOSSY /ALUTERV-FKI, Hungary/, who detected the chamositic bauxite of Iran.

The Sar-e-Fariab /or Behbahan/ bauxite was discovered by SAMIMI /12, in 1966/ in the Middle Cretaceous series in the High Zagros Mountains.

Yazd bauxite was discovered by VALEH /Geological Survey of Iran/, and Shiraz or Daryush Dam bauxite was discovered in 1967 by MOVAHHED /GSI/.

SAMIMI and SHARIFI /13, in 1969/ described at first the Do-Polan kaolin and bauxite deposit in the High Zagros Mountains.

BARNABÁS and SZANTNER /2, in 1969/ of the Hungarian Aluminium Corporation visited the Do-Polan, Behbahan and Shiraz bauxite deposits and the Semirom and Amol refractory clay deposits. This was the first comprehensive study of the chemical and mineralogical properties of the Iranian bauxites. Their report comprised the wet chemical analysis of the main components and of minor impurities, emission spectrography of some trace elements, radiometry of radioactive elements, thin section determinations with photomicrograph in colour, derivatography /DTA-DTG-TG curves/. X-ray diffractometry, bulk density and specific weight determinations and even laboratory scale tests on the alumina technological behaviour of four average samples.

DE LAPPARENT /4, in 1969/ investigated the paleogeography of Cretaceous bauxites of the Sar-e-Fariab area and distinguished two bauxitic horizons in the Yazd deposit: one between the Lower Carboniferous and Upper Permian and another between the Upper Permian and the Shemshak Formation /Jurassic/.

Following an interpretation of aerial photos and subsequent field works completed by VALEH /GSI/ reconnaissance work has been done on two bauxitic horizons of Jajarm deposit, Elburz Mountains.

In 1972 BALKAY /Hungarian Aluminium Corporation/ and SAMIMI /GSI, 1/ evaluated the Sar-e-Fariab, Shiraz, Do-Polan and Jajarm bauxitic regions and that of some flint clay deposits as well.

Also in 1972 a detailed report /5/ written by DUDICH /Hungarian Geological Institute/ summarized the geochemistry and mineralogy of bauxite in Iran.

In 1978-79 an Iranian-Czechoslovakian expedition was working in the bauxitic region of Zagros Mountains /6/.

In 1983 and 1984 reports were completed by ALUMIRAN /8, 9, 1o/ on the Jajarm, Shirin Abad - Siah Rudbar and Ganu regions, the results of which are summarized in Chapter II/B, C, D.

Regarding the areas prospecting for alunite two earlier Reports have to be mentioned: NEMAT and ZEINALOV /7, in 1977/ and TAGHIZADEH et all. /14, in 1983/ investigated the prospectivity of alunites of Iran. These reports include the complete list of references in connection with Iranian alunites.

B. Jajarm region /9/

The Zoo Mountains are at a distance of 1o-15 km N-NE from the small town Jajarm and ranges to East at about 4o km length.

1. Geological situation

Two bauxitic horizons are known here:

- Horizon A: between the Mobarak /Carboniferous/ and Elika /Triassic/ Formations. The bauxite is not continuous in the Horizon. The deposits are of lense or pocket types.
- Horizon B: between the Elika and Shemshak /Jurassic/ Formations. The bauxite is of the layer-type. The total mapped /at 1:2o.ooo scale/ length is 12 km, the average thickness of the hard bauxite is below 2,5 m.

The area is strongly tectonised, but well exposed due to the semi-desert climatic conditions no vegetation covers the surface. Consequently, an aerophoto based exact interpretation can clear the geomorphological and tectonical situation.

In both of the two horizons exist a very hard, reddish-brown or /originally/ dark grey bauxite and towards the footwall a soft, lighter reddish-brown bauxitic clay and clayey shale.

2. Chemical, mineralogical and technological analysis

Results of earlier analysis were summarized in the BALKAY-SAMIMI Report /1/. According to their investigations the main characteristics are as follows:

- based on the analysis of 1oo commercial /Bayer or LSS=lime+soda+sinter/ grade samples the average chemical composition of which is:

  Al_2O_3 52,o %
  SiO_2 1o,1 %

- four samples were mineralogically analysed by X-ray diffractometry:

diaspore	44,8 - 66,8 %
kaolinite	4,8 /in one sample/
chamosite	2,o - 35,7 %
illite	5,o - 23,o %
hematite	6,4 - 12,7 %
anatase	3,o - 5,1 %

The ALUMIRAN Report /9/ includes the results of about 4oo analysis of hard bauxite samples and that of about 25o analysis of soft bauxitic clay or shale. The average composition of hard bauxite is as follows:

Al_2O_3	46,6 %
SiO_2	13,3 %

In 1984 BULKAI's Report /3/ is evaluating the results of mineralogical and alumina technological characteristics of an average sample /No. JJT-4/ of Jajarm deposit, Horizon B. The results are as follows:

Al_2O_3	43,7 %	diaspore	35,7 %
SiO_2	12,5 %	boehmite	-
Fe_2O_3	27,2 %	kaolinite	-
TiO_2	4,9 %	chamosite	52,7 %
L.o.i.	1o,3 %	halloysite	-
CaO	o,2 %	chlinochlor	-
MgO	o,1 %	hematite	5,5 %
P_2O_5	o,2 %	anatase + rutile	4,9 %
others	1,1 %	calcite	-
total:	1oo,2 %	total:	98,8 %

The recovery factor for alumina at 25o° temperature:

with 6 % CaO:	68 %
with 3 % CaO:	58 %

The recovery factor is not high, but the diaspore content of the sample was very low. The test proved, that about 98 % of the alumina content of the diaspore is recoverable /29,7 % Al_2O_3 content in comparison with the chemically analysed 43,7 % of total Al_2O_3 content of the sample/. According to the earlier analysis /1/ an average 5o % of diaspore content can be supposed. In that case the recoverable alumina content of the sample can be about 42 %. By other words the bauxite recovery factor in this case /tons bauxite for one ton of alumina/ is about 2,5.

3. Estimated resources

The estimation is based on the UN Classification /15/. Total estimated resources of hard bauxite of Horizon B can be estimated in category P-3 /ALUMIRAN estimation/ as follows:

Block	length m	width of extrapolation m	average thickness m	spec. weight	resources million t
I. /Western/	3900	270	2,15	3,0	6,8
II. /Western part of Middle/	3600	330	2,8	3,0	10,3
III. /Eastern part of Middle/	2500	200	1,2	3,0	1,8
Total	10000				18,9

It has to be mentioned, that with such length of outcrop the width of extrapolation can be assumed - in category R-3 - to be 500 m. In that case the estimated resource in category R-3 is about:

32 million tons.

C. Siah Rudbar - Shirin Abad region /1o/.

The area is 2o km southeast from Aliabad in the Elburz Mountains. The elevation is between 7oo and 17oo m.

1. Geological situation

A general geological map at scale 1:25.ooo and two geological maps at 1:1o.ooo scale are available for the two parts of area. The footwall of Bauxitic Horizon is the fairly karstified dolomite of Elika Formation /Triassic/. The Bauxitic Horizon is covered by sandstone of Shemshak Formation /Jurassic/.

According to the data of a preliminary phase of prospecting by geological mapping, the bauxite is either layer, or probably elongated lense type. The thichness of the hard bauxite of the Horizon is changing from less than one meter to more than 2o meters. Due to the different tectonic movements the inclination of the Horizon is changing from horizontal to vertical.

Tha Bauxitic Horizon is limited on the NE side /Siah Rudbar/ by a fault, but forther continuation can be assumed. The SW part is not geologically limited, but extending outside the reconnaissance area.

2. Chemical, mineralogical and technological analysis

Totally 427 samples were chemically analysed, most of which were hard bauxite. The chemical analysis are not tabulated in the Report /1o/. The average chemical composition of hard bauxite is:

Al_2O_3	about	44 %
SiO_2	"	18 %
Fe_2O_3	"	19 %
TiO_2	"	2 %
L.o.i.	"	1o %

The results of qualitative mineralogical analysis are as follows:

diaspore, boehmite, chamosite, clay minerals.

One sample /No. SRT-3/ was analysed by quantitative phase analyses /3/, the result of which is:

Al_2O_3	45,5 %	diaspore	36,2 %
SiO_2	16,2 %	boehmite	2,4 %
Fe_2O_3	21,6 %	kaolinite	14,1 %
TiO_2	2,9 %	chamosite	42,6 %
L.o.i.	11,o %	halloysite	-
CaO	o,1 %	chlinochlor	-
MgO	o,9 %	hematite	-
P_2O_5	o,2 %	anatase + rutile	2,9 %
others	1,6 %	calcite	-
Total:	loo,o %	Total:	98,2 %

This sample was tested for the recovery of alumina, the result of which was as follows:

recovery factor for alumina at 25o° temperature with 3 % CaO:

6o %

The relatively low recovery factor /total recoverable alumina 27 %/ can be due to secondarily altered type of bauxite indicated its boehmite content and mainly by the high kaolinite content. Deeper, unaltered part of the bauxite is expected to contain less or no kaolinite /and boehmite/ and more diaspore. In this case the recovery factor can be higher.

3. Estimated resources

The resources estimated by Sazand Iran Consulting Company /subcontractor of ALUMIRAN/ is about 25 million tons /category R-3/ of hard bauxite, but regarding to the very hypothetical structural situation and due to the few data available it can be strongly change by future investigations.

D. Ganu region /8/

The area is located at southeast of Fulad nahaled and is about 75 km West of Damegham. The elevation is near or more than 2200 m.

1. Geological situation

Presently 1:25.000 scale geological and 1:5000 and 1:50.000 scale reconnaissance maps are available. According to the results of mapping up to date the footwall is the fairly karstified dolomite of Elika Formation /Triassic/: the Bauxitic Horizon is covered by sandstone and/or shale of Shemshak Formation /Jurassic/. The tectonic situation indicates an overturned structure.

The bauxite is layer-type, the length of the mapped horizon is about 5 kms. The average thickness of hard bauxite is estimated to 3,5 m. Similarly to the other late Elika bauxite deposits of the Elburz Mountains the bauxitic profile of the Horizon contains hard and soft /clayey/ bauxite types and more or less shale.

2. Chemical, mineralogical and technological analysis

About 500 samples of hard bauxite were chemically analysed, the average chemical composition of which is as follows:

Al_2O_3	about	49 %
SiO_2	"	14,4 %
Fe_2O_3	"	19 %
TiO_2	"	3,9 %
L.o.i.	"	11,5 %

Results of qualitative mineralogical analysis are: diaspore, gibbsite /traces/, boehmite, quartz /traces/, kaolinite, chamosite, halloysite, goethite, anatase, rutile and calcite.

BULKAI's Report /3/ gives phaseanalyses and alumina technological test of one sample /No.-GAT-1/ as follows:

Al_2O_3	49,0 %	diaspore	43,1 %
SiO_2	14,4 %	boehmite	-
Fe_2O_3	19,0 %	kaolinite	15,6 %

TiO_2	3,9 %	chamosite	13,5 %
L.o.i.	11,3 %	halloysite	5,8 %
CaO	o,6 %	chlinochlor	o,8 %
MgO	o,4 %	hematite	15,5 %
P_2O_5	o,2 %	anatase + rutile	3,9 %
others	1,4 %	calcite	1,o %
Total:	1oo,2 %	Total:	99,2 %

The recovery factor of alumina at 25o° temperature with 3 % CaO:

74 %

Regarding the probably altered surface sample /kaolinite, halloysite/ the recovery factor of a deeper, unaltered original /dark grey/ type of bauxite can be expected to be higher.

3. Estimated resources

Applying the UN Classification /15/ the resources can be estimated - based on the ALUMIRAN data - in category R-3 as follows in two variations:

length	5ooo m	5ooo m
width of extrapolation /depth/	2oo m	5oo m
thickness	3,5 m	3,5 m
specific weight	3,o	3,o
Total resources:	1o,5	26,2
	million tons	

III. ALUNITE RESOURCES

A. Earlier investigations

According to the earlier investigations /7, 14/ over 1000 km long Tertiary volcanic Formation is elongated through Iran from NW to SE, many part of which are more or less altered to different products. By such secondary effects the acidic volcanics - mainly rhyolite and partly andesite tuffs were altered to alunite.

Well completed reconnaissance geological mapping indicates very large resources W-NW of Tehran at about 200-250 km distance. Up to date six highly alunitised regions are known in this region the length of which is about 120 km. The regions are from NW to SE: Zaykandy /in two parts/, Sirdan, Hassanabad, Zaykan and Taykand.

The mapping was supported by surface sampling and trenching /totally 20 trenches/, and by two galleries and one quarry /both in the Taykand region/. 1:5000 scale geological maps are available on the Sirdan and Hassanabad regions and 1:25.000 scale one on the Taykand region.

B. Composition of alunite

Detailed data are available presently only in Pharsi language in the two Reports /7, 14/. The alunite content of regions mentioned above is varying from 30 to 70 %. Quantitative mineralogical analysis are not available.

Considering the chemical composition of alunite:

$$KAl_3[(OH)_6(SO_4)_2]$$

where K may be substituted by the elements of Na, or by Sr, Pb, Ag, Y, Ce or other Rare Earth elements and

where Al may be substituted by Fe^{3+}

forming the Diadochy of the Alunite Serie from alunite over jarosite to karphosiderite. However, mainly sodium may substitute potassium in the mineral structure. For example in the alunite deposit on the Milos Island /Greece/ the ratio is 6:1.

Regarding to the original composition of alunite and calculating with 3 different cut off grades of alunite content /prospection cut off, mining cut off and beneficiation cut off/ the compositions are as follows:

Main constituents expressed as:	Pure alunite	cut off grade 35 % alunite	grade run of mine 5o % alunite	enriched alunite: 75 % of alunite
Al_2O_3	37,o %	13,o %	18,5 %	27,7 %
H_2SO_4 /SO_3/	35,5 % /38,5 %/	12,5 %	17,7 %	26,6 %
K_2SO_4 /K_2O/	21,o % /11,3 %/	7,3 %	1o,5 %	17,7 %
H_2O	6,5 %	2,3 %	3,2 %	4,9 %

With an alunite content of above 35 % it can be considered as a potential raw material for the production of alumina and the by-products.

C. Estimated resources

The GSI Report /14/ estimates the resources with more than 3o % of alunite. These resources were re-estimated by ALUMIRAN and MADANKAV /subcontractor of ALUMIRAN/ using the same data of GSI but with 35 % cut off for alumina content. The results are as follows:

Area	GSI estimation	ALUMIRAN estimation
	million tons	
Hassanabad	165	136
Sirdan	235	68
Zaykan	84	6o
Zaykandy	118	76
Total:	6o2	34o

Based on the newer results of mapping and that of the newer analysis of 3 smaller deposits of Taykand area /Taykand, Haftsandogh and Solydareh/ the resources of these deposits were estimated by ALUMIRAN and MADANKAV to:

more than 100 million tons

of alunite with more than 35 % alunite content.

According to the consultants's opinion all estimation of alunite resources can now be classified into the R-3 category of UN Classification System /15/.

The specific weight with which the resources mentioned above were calculated is 2,78 according to ALUMIRAN's information.

IV. CONCLUSIONS AND RECOMMENDATIONS

A. Conclusions

1. The capacity of an alunite based alumina plant is limited in Iran by the by-prcduct of sulphuric acid to maximum 2oo.ooo tons of alumina per year. Based on the Government's plans to produce 6oo.ooo to 8oo.ooo tons/year alumina in the early 199oies - and excluded the import of bauxite as well - detailed and very careful prospection and exploration of suitable ore-grade bauxite deposits with economic mineability and sufficient mineable reserves is an indispensible task.

2. The final decision for development of alunite or/and bauxite based alumina plant/s/ can be done only after the completion of Feasibility Studies for both raw materials in 1986.

3. Based on the data of prospection works up to date the bauxite resources of three regions of the Elburz Mountains can be estimated in category R-3 of UN Classification /15/ as follows:

resources in million tons

Region	with 2oo-33o m width of extrapolation	with 5oo m width of extrapolation
Jajarm	19	32
Siah Rudbar - Sirin Abad	35[x]	
Ganu	1o	26
Total	64	93

[x] due to the early phase of prospection only in one variation

4. The bauxite of the Elburz Mountains is mainly diaspore-chamositic type, similarly to some other Iranian bauxites /Yazd, Do-Polan, etc./ investigated before.

5. Diasporic bauxite is suitable for economical production of alumina by modified Bayer technology /Greece, Turkey, Soviet Union, Rumania/.

6. Chamosite in diasporic bauxite is not reactive in the process at well tested moderate temperature. Consequently, it is expected, that alumina can be produced economically by this technology as it was proved with a similar type of bauxite from North Vietnam by ALUTERV-FKI /Hungary/ in laboratory scale.

7. Preliminary technological tests made on Elburz bauxites indicate also the possibility of economical recovery of alumina from the diaspore-chamositic bauxite.

8. ALUMIRAN is capable to undertake the necessary prospecting and exploration works, but these works both for alunite and bauxite have to be concentrated for the most prospective deposits and have to be continued without any further delay.

9. Huge alunite resources has been prospected during the past few years by the Geological Survey of Iran /GSI/. The most promising deposits are believed by ALUMIRAN to be the Taykand deposit sited about 250 km NW of Tehran.

According to the ALUMIRAN's re-estimations the alunite resources of the prospected regions are as follows /according to the UN Classification in category R-3/:

resources in million tons

Area	resources with more than 35 % alunite
Hassanabad	136
Sirdan	68
Zaykan	60
Zaykandy	76
Taykand	100

10. According to the consultants' opinion the regular sequence work on the alunite investigation should be an extensive prospecting and exploration campaigne to permit a final decision for the optimum selection of the deposit followed by mining exploration for computing a representative sample. The required time would be 2-3 years.

11. However, within a UNDP-UNIDO sponsored alunite Project it is intended to draw soonest characteristic samples and after their examination a 25o tons "representative" sample from the most promising deposit in the Tayband area. The ore shall be upgraded and processed in a pilot plant by VAMI /Leningrad, Soviet Union/.

B. Recommendations for bauxite exploration

General recommendations

The planning of bauxite mines and engineering of mine installations, beneficiation plants, bauxite transportation systems and to a great extent the future alumina plant are virtually based on the data of the deposits obtained by prospecting works even in an early and preliminary stage and finally by exploration.

The handling of such a Project involves a most exact determination and evaluation of exploration data.

Modern and sophisticated methods must be applied in the evaluation of the deposit information for establishing the mineral resources and mineable or recoverable ore reserves, which form the basis of all future relevant technical and economical considerations.

By previous prospecting works and based on the results during a preliminary exploration phase only the "in situ" R-3 and partly R-2 geological resources can be established in the three areas under consideration. Therefore after detailed verification and evaluation of all these data available up to date, a first attempt should be made to compute mineable ore reserves based on a systematic future exploration work.

For the better evaluation of previous deposit information the following works should be performed:

- completion and interpretation of geological mapping at a scale 1:1o.ooo till 1:25.ooo as already applied in the three areas,
- interpretation of available aerial photographs and preparation of colour aerial photography, limited to the reconnaissance project area,
- satellite imagery, if it is available, in a reasonable period of time should be evaluated,
- interpretation of sampling results in relation to the geological and mineralogical data,

- statistical investigation of inhomogenity and analysis of inhomogenity - two and three dimensional,
- geostatistical level and block resource and reserve calculationsincluding varigram analyses and kriging,
- determination of cut-off variations.

The strategic planning of future prospecting and the tactical details of exploration by drilling, mining cuts and adits in the three areas under consideration must have the target to establish the mineable quality and characteristics of the deposits having an impact on mine preparation and exploitation.

During the future exploration phase the information generated will be manifold and numerous. In order to make the problems of an appraisal and a feasibility manageable it is from now on necessary to break them down into component phases:

- samples assign /x,y,z/ for statistical and geostatistical analysis and values,
- weighted sample composits,
- bench composits,
- thickness composits,
- deposit width composits,
- creat mineral inventory,
- ore reserve summation,
- and finally: feasibility and economic analysis.

Great attention must be paid to the proper recording of sample data. Bauxite sampling in all three areas is a costly process. One of the great advantages applying computer is the ability to store and manipulate vast quantities of data, provided the recording of sample data is made onto forms suitable for computer manipulation and storage.

A suitable program should be selected soonest in cooperation with a firm experienced in computer assisted mineral assesment and feasibility studies.

Analysis and interpretation of characteristic samples

Following works are recommended assoon as possible:

- chemico-mineralogical and phase analyses/testing of bauxite samples:

- collection of 4o-45 samples from ore deposits: delivery to testing laboratory,
- bauxite geologist and mining consultants expertise,
- testing of 4o-45 samples with interpretation of results - submission of Report to ARMP,

- bench-scale technological testing of bauxite with techno-economic opportunity study of their industrial processing to alumina in Iran:
  - collection of 4-5 characteristic samples /2-3oo kg each/; delivery to subcontractor's facilities,
  - testing of samples and preparation of opportunity study by subcontractor with submission of Report to ARMP.

Regarding the different alumina recovery factors of altered and unaltered bauxites great attention must be paid to the sampling of both altered and original, unaltered /generally grey, dark grey/ characteristic bauxite samples.

Other general recommendations

- For further better organized and less expensive works buying of own drilling machines is recommended to ALUMIRAN,
- any drilling program should be completed in any area only following the finalization of 1:2ooo scale geological mapping,
- considering the great distances in the three areas and from Tehran and regarding also the very hard access conditions to the deposits the usage of helicopter and/or small aeroplane/s/ can be proposed. Landing strips can very easy and quickly be prepared,
- all data of any type of analyses have to be included into any further reports,
- regarding the cooperation between Iran and UNDP-UNIDO also in the future, the consultants propose to write all following reports in English, too. In the case of Pharsian text a detailed summary, tables of analysis and the legend of maps should be written also in English,
- for further classification of resources and reserves the "UN-Classification Method" is recommended /15, see App. No. 2./.

C. Local recommendations for bauxite works

1. Jajarm area

Prospecting and exploration works are recommended by the following master chart:

x = quarter of year

No.	description	1984	1985	1986	1987
1	Topographical survey for road construction to the exploration area	x			
2	Approval of road construction by authorities, land acquisition	x	x		
3	Construction of road to BI area /West/ 6ooo m, width 6 m		x		
4	Access roads to the outcrops and exploration area: 5ooo m, width 4 m		x		
5	Interpretation of aerial photographs by specialized experts	x			
6	Coloured aerophotography of BI, BII, BIII areas and interpretation	x	x		
7	Marking of deposit border lines in the field for quick survey /points/	x			
8	Topographical survey of No. 7 points and map at 1:2ooo scale	x	x		
9	Preparation of maps 1:2ooo from aerophotographs and combined with No. 8	x	x		
1o	Generate geological map 1:2ooo BI and BII /W part/		xx		
11	Elaboration of detailed exploration program for BI-BII		x		
12	Sampling of outcrop /attention to recording/ in limited section of deposit BI	x	x		
13	Assays, mineralogical examination, technological tests on No. 12. samples		xxx		
14	Execution of shallow non-core drillings BI area, 15oo m		xx		
15	Non-core and core drilling cont. depth>7o m<15o m, 2ooo m		xx	x	
16	Evaluation of samples from drillings		xx	xx	
17	Elaboration of mineral inventory - mine prefeasibility study			xx	
18	Exploration gallery >7 m² < 1o m² mainly if No. 17 is positive, about 5oo m		x	x	x
19	Drilling continued to East of BI, 2ooo-3ooo m, depth 5o-15o m			xx	xx
2o	Drillings in the BII and BIII: 3ooo m, depth 5o-2oo m				xxx
21	Mining Feasibility Study				xxx

2. Siah Rudbar and Shirin Abad area

- To continue the reconnaissance by evaluation of existing aerial photographs,
- to produce colour aerial photographs of the area mapped at 1:25.ooo scale with extension to SW,
- airborne and ground survey in the SW part of the prospecting area
- continue and complete surface geological mapping at 1:1o.ooo scale connected with mapping on aerial photographs. The expected bauxitiferous contact of the Elika and Shemshak Formations should be paid special attention by indicating any observed occurence in the map,
- already known outcrop/s/ of bauxite NE of Siah Rudbar in the Dularam Valley to be mapped at 1:2ooo scale. Procedure as mentioned later for the Ganu area,
- percussive drillings in this deposit from the hanging wall to the footwall /vertically to the dip/ for sampling,
- analyses of samples - chemical, mineralogical and technological investigations. If positive results will be achieved than to continue the exploration of the deposit with further drillings and by exploration gallery. Sampling and recording of samples similar procedure as given for the Ganu area.
- For the Shirin Abad area the following details are recommended:
  - 8-1o prospecting trenches along the bauxitiferous contact in the northern flank of the Qozloq River Valley /S17-T16-S28 observation sites of earlier prospections/,
  - 1o prospecting trenches or/and shafts between T17 and S29 /observation sites/ on the contact of the Elika and Shemshak Formations to prove the existance of a bauxite layer of a mineable thickness,
  - detailed survey of an E-W Zone south of the village Shirin Abad between elevation 1o5o and 12oo m. Within this Zone bauxite has been observed in a "window" the Elika Formation /Triassic/ is outcropping,
  - in case the prospecting work has confirmative results an exploration program should be elaborated for this area. However, the examination of the samples should also include technological test for the processing of alumina from this ore.

3. Ganu area

- Indicate the contact of bauxite layer with the hanging wall and the footwall and any tectonic feature lines on the site by painting numbers on the rocks,
- indicate main tectonic pattern within the exploration target area by painting current numbers on the rock,
- topographical survey of all indications made in works menticned above at a scale 1:2ooo. Subdivide the total length of outcrop /5 km/ into proper section by the map 1:2ooo,
- detailed geological mapping in scale 1:2ooo, statistical tectonic structure analyses to secure optimum selection of location for drillings connected by vertical sections,
- access road to the selected areas. The inclination of such roads should not exceed lo % and should be in average up to 5-7 % only,
- exploration of a selected and limited length of the deposit /looo-15oo m/ showing a minimum of tectonic disturbance of the bauxite layer according to mapping as was mentioned above,
- beginning with the sampling of outcrops in this selected area,
- transfer all previous data derived from the interpretation of aerophotographs, prospecting, sampling and analysis into the map by generating a preliminary mineral inventory,
- prepare all previous information concerning this part of the deposit for computer storage and manipulation according to the requirement of the selected computer program,
- non-core drilling till the bauxite layer using air or water flushing. Coring only in the ore. If core recovery is low /less than 7o %/ core and cuttings to be collected to a composite sample and recorded carefully,
- geologic and core logging in computer oriented forms,
- select site of an adit, proceed until the bauxite layer and about 2oo m along the strike of the deposit. The gallery should be opened close to the hanging wall in the hard bauxite layer with cross cuttings to the footwall in 3o-5o m intervals,

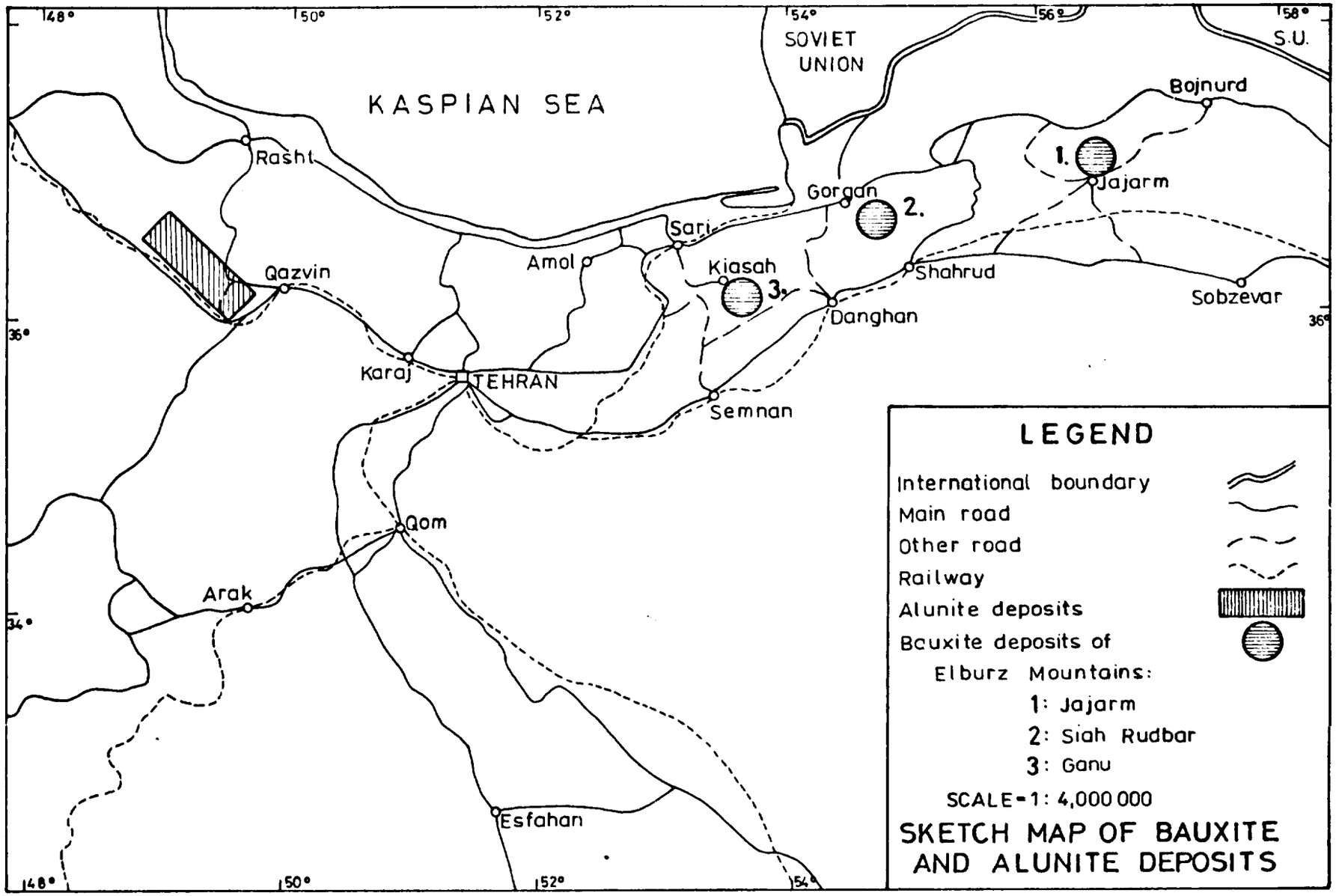
- by muck as well as channel and pick sampling the ore grade should continuously be controlled and results compared. The total accessible portion of the orebody to be mapped carefully,
- draw separately representative samples from the stockpile at the head of the gallery derived from the bauxite layer and the cross cuts,
- further investigation of the deposit should proceed after the establishment of the explored mineral inventory connected with technological examination of the ore.

D. Recommendations for alunite exploration

Under the given circumstancies consultants agree to select Taykand deposit for further consideration. As immediate steps are proposed to elaborate an exploration program for a limited area of about 1 km² at the site Haftsandogh as follows:

1. access roads in two levels passing closely to the existent exploration galleries. These roads give simultaneously access to the exploration sites and permit channel and pick samplings along a remarkable distance within the deposit,
2. To continue the 2 galleries and penetration of the deposit at the end of the gallery by a vertical or inclined shaft till the surface.
3. Shallow percussive drillings of 2o-3o m depth from the surface of the deposit along the access roads and random spaced within the 1 km² exploration area.
4. Suitable recording of all sampling points for computer assisted mineral assesment and preliminary mine planning.

Minimum time required for the execution of above works is 6 months depending on quick approval of the working program by the authorities including the permission for the use of explosives, availability of suitable equipment and skilled manpower, and finally depending on facilities available for sampling and analysing procedures in order to be able to guide continuously the exploration works.



Appendix No.1.

Appendix 2.

UN International Classification of Mineral Resources /1979/.

Classification categories: R /capital/ : resources "in situ" of economic interest for the next 2-3 decades
r /lower case/: recoverable resources /reserves/ closely calculated for mineral supply.

R-1

Encompasses the in situ resources in deposits that have been examined in sufficient detail, sizes and qualities known, technology established. Relevance of such estimates is the planning of mines.
Error of estimation less than 5o %.

- **R-1-E**: Economically exploitable believed to be workable with profit with regard to thickness, depth, grade
- **R-1-S**: Subeconomic, prefix "sub" denotes under, below, less than normal, amount, contains small portions.
  - **R-1-M**: Marginally economic, a deposit near the lower limit of commercial workability which can be exploitable in short due to economical and technical changes.

R-2

Estimate of in situ resources that are associated with discovered deposits, quantities are preliminary and largely based upon broad geological knowledge, supported by measurements at some points. Estimation error above 5o %. Estimates relevant for planning of further exploration for R-1 resources.

- **R-2-E**
- **R-2-S**
  - **R-1-M**

R-3

Undiscovered in situ resources that might exist based on geological extrapolation. R-3 indicate exploration opportunities, quantities known in ranges.

Not subdivided further

The "recoverable resources" are classified accordingly as r-1, r-2, r-3. The definition of recoverability and the point it will be measured in the exploration, mining and processing sequence must be established for each commodity.

- **r-1**
  - **r-1-E**
  - **r-1-S**
    - **r-1-M**
- **r-2**
  - **r-2-E**
  - **r-2-S**
    - **r-2-M**
- **r-3**

not subdivided further

Appendix No. 3.

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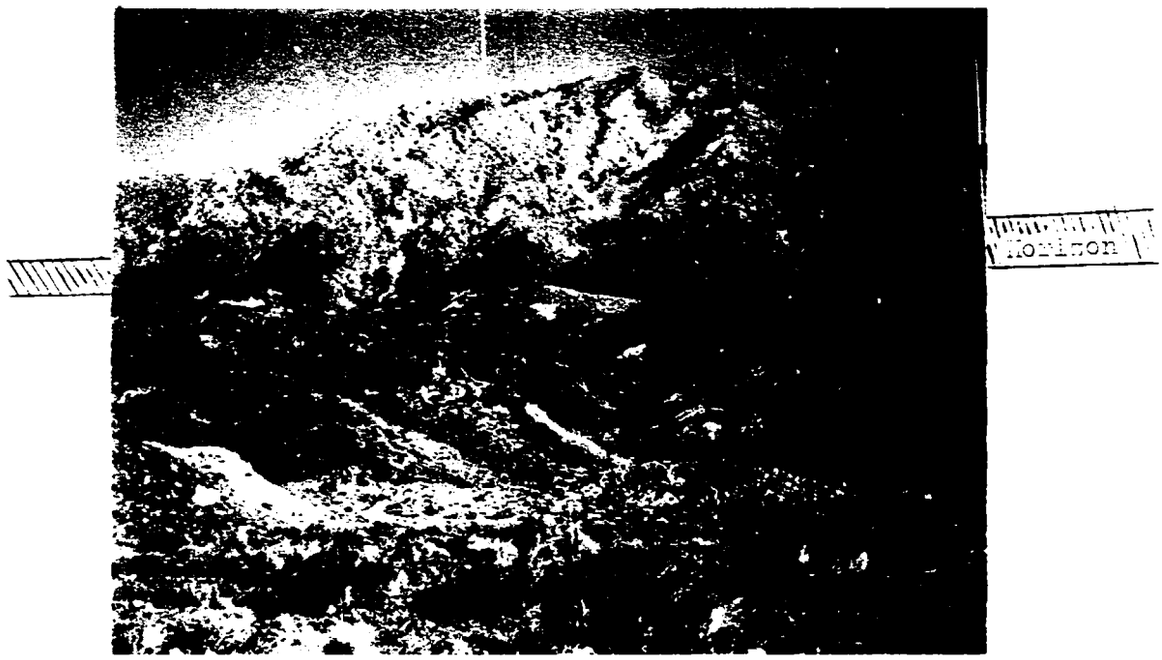

Photo No.1: Jajarm: Western Block:
Bauxitic Horizon B.

Photo No.2: Jajarm: Western Block: Horizon B:
bauxite outcrop at the trench No.1.

Photo No.3: Jajarm: Western Block, Horizon B:
Trench No.1.

Photo No.4: Jajarm: Western Block, Horizon B:
Trench No.1: soft /left/ and hard
/right/ bauxites.

Photo No.5: Jajarm: Western Part of Middle Block: Horizon B: steep bauxite wall.

Photo No.6: Jajarm: Western Part of Middle Block: Horizon B: outcrop of hard bauxite.

Photo No.7: Jajarm: Eastern Part of Middle Block: Horizon B, outcrop of hard bauxite.

Photo No.8: Jajarm: Eastern Part of Middle Block: Horizon B: original /grey/ diaspore-chamositic and altered /reddish-brown/ clayey bauxite /in the fissures/.

Photo No.9: Siah Rudbar:
Trench No.2.

Photo No.10: Siah Rudbar:
steep bauxite wall below
the observation point
No.30.

Photo No. 11: Ganu: outcrop of hard bauxite.

Photo No.12: Taykand area: panorama of alunite-rich hills.

Photo No.13: Taykand area: Taykand deposit: adit in high-grade alunite.

Photo No.14: Taykand area: Taykand deposit: dust-sampling from shallow prospection drilling.

Photo No.15: Zaykandy alunitic area: prospection trenches.

Photo No.16: Zaykandy alunitic area.