Geological Formations as Repositories of Radioactive Waste Products: A Review of Indian Geology

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CERTIFICATE

Certified that the work embodied in this dissertation entitled **"Geological Formations as Repositories of Radioactive Waste Products: A Review of Indian Geology"** has been carried out in the School of Environmental Sciences Jawaharlal Nehru University New Delhi. The work is original and has not been submitted in part or in full any other degree or diploma in this or in any other University.

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Place - SES JNU,
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CHAPTER - I

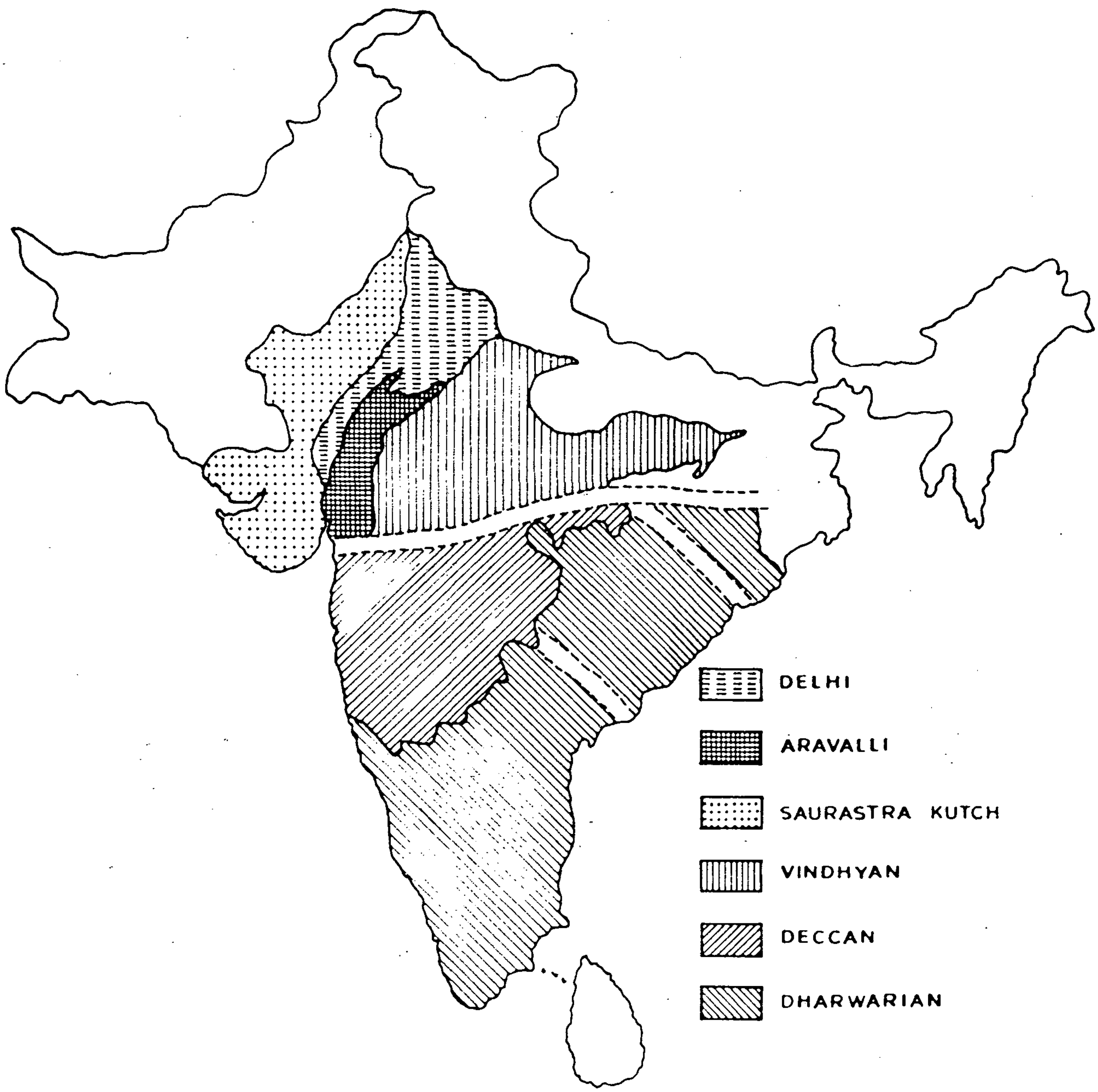
1. INTRODUCTION

1.1 RADIOACTIVE WASTE AND DISPOSAL

Radioactive waste is any material that contains or contaminated with radionuclides at concentration or radioactivity levels greater than the exempt quantities established by the competent authorities and for which there is no use foreseen [IAEA, 1981]. Such materials that are no longer useful to man become waste and that must he kept isolated from the human environment as long as potentially harmful levels of radioactivity exist within them. The radioactivity and thus the radiotoxicity of these wastes is allowed to decay to lover levels with time at rates depending upon the half lifes of the specific radionuclides and their daughter products. For most radionuclides the half lives vary from about 1 year to thousands of year or more.

Thus radiation protection of man is needed over a long period of time and it is incumbent on all nations that produce radioactive wastes to limit radionuclide release into the human environment to the level that are compatible with the requirements of radiation protection.

Disposal on the other hand may be defined as the



GENERALISED TECTONIC MAP OF INDIA

COMPILED FROM THE TECTONIC MAP OF INDIA
BY
GEOLOGICAL SURVEY OF INDIA 1963
AND
OIL & NATURAL GAS COMMISSION 1968

Fig.1.1

emplacement of waste material in the repository without the intention of retrieval and it differ from the storage where the intention will be to retrieve it at later time [IAEA, 1981].

1.2 RADIOACTIVE DISINTEGRATION AND RELATED PHENOMENA

All elements with atomic numbers greater than 83 are radioactive and the emission of α, ß particle and Γ-particle from this heavy atoms is called radioactive disintegration [Mishra 1978]. In fact the instability of heavy atoms is due to the instability of their nuclei. During the disintegration of a radioactive atom the nuclei of the atom breaks down with the formation of a new nucleus and the emission of α or ß particle. This means that α and ß particles come out of the nucleus. The ß-particle is not an electron removed from the outer sphere of the electron, but one originating from the nucleus. Thus it is also known as nuclear phenomena.

The nucleus of any atom contains only proton and neutrons. The emission of an α particle is a helium nuclear He^{++2} containing two proton and two neutrons. However, the emission of an electron or ß particle from the nucleus is difficult to understand. But as it is believed that the emission of a ß-particle from the nucleus of an atom is due to the conversion of a neutron into a proton and an electron such as

$$_{o}n^{1} \text{---------->} \ _{+1}p^{1} + \ _{-1}e^{o}$$

Neutron proton electron

1.3 EFFECTS OF THE LOSS OF α AND β PARTICLES AND Γ-RAYS:

The loss of an α or β particle from the nucleus of an atom of an element results in the formation of a new element where as the emission of Γ rays does not create any new atoms because it possesses no charge and no mass.

1.3.1 Loss of an α-particle:

When an α-particle is emitted, the mass number of the resulting nucleus is decreased by four unit and the atomic number is by two unit = as because the α-particle contain two neutrons and two protons (i.e., mass number = 4 and charge = +2)

Thus it can be represented as

$$_{a}A^{m} \text{---------->} \ _{a-2}B^{m-4} + \alpha^{4} \text{---------}$$

$$\text{e.g. } _{92}U^{238} \text{------>} \ _{90}th^{234} + \ _{2}\alpha^{4}$$

Where

m = mass number

a = atomic number

1.3.2 **Loss of a ß-particle**:

It is believed that electrons are produced in the nucleus by the decay of neutrons as

$$_{o}n^{1} \text{ --------> } _{+1}p^{1} + _{-1}e^{o} \text{ (ß-ray)}$$

So for the emission of a ß-ray from the nucleus one neutron is converted into a proton. Total mass of the nuclear remain the same but there is an increase of one unit is the positive charge of the nuecleus. Hence the loss of a ß-ray results whose atomic number is one unit greater than that of the decaying element as :

$$_{a}X^{m} \text{--->} _{a+1}Y^{m} + _{-1}e^{o} \text{ (ß-ray)}$$

where,

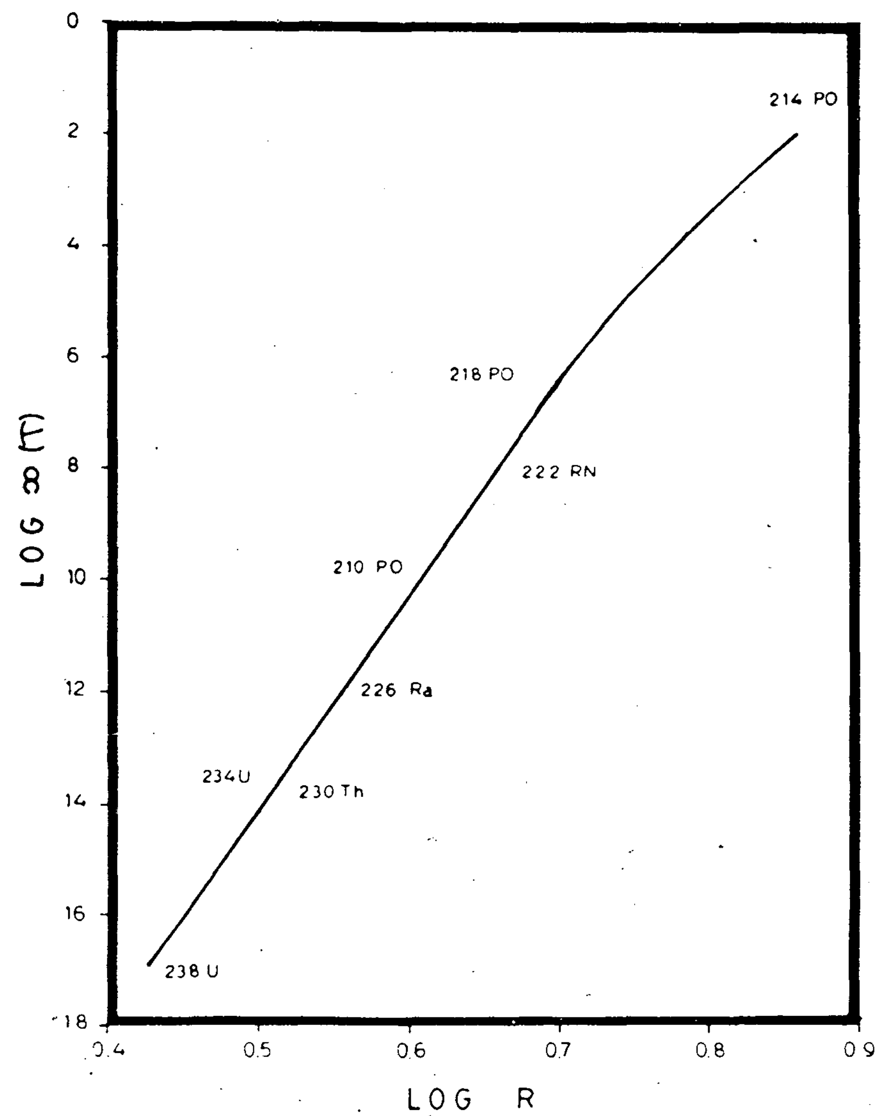
m = mass number

a = atomic number

e.g., $_{90}Th^{234} \text{--->} _{91}Pa^{284} + _{1}e^{0}$ (ß-ray)

1.3.3 **Loss of Γ-rays**:

As the Γ-particle neither possess charge nor mass the emission of this particle will not form any new element, but because it is similar in nature to x-rays having shorter wave length, it causes certain ionising effects on



A GEIGER NUTTAL PLOT OF THE ALPHA EMISSION FROM THE EVEN Z, EVEN N NUMBER OF U SERIES

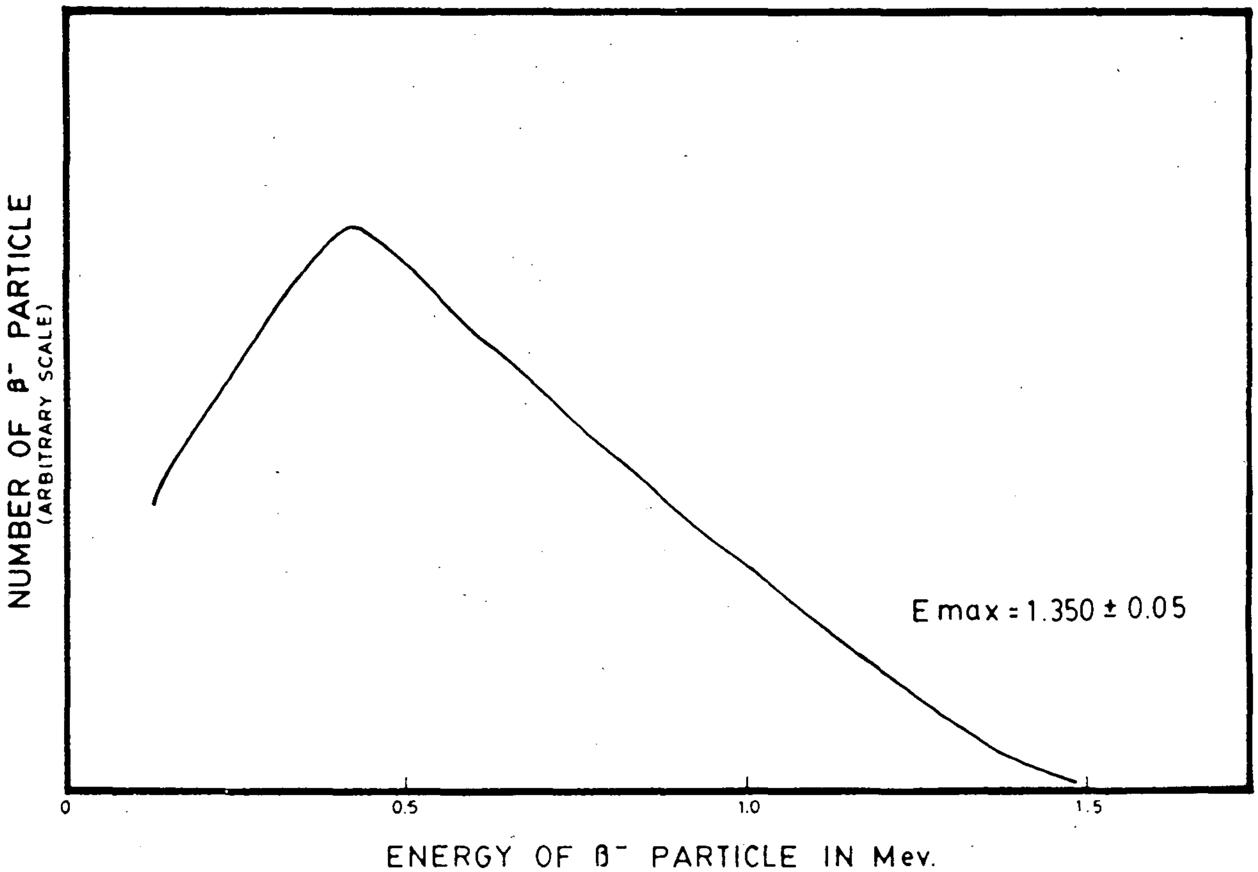
(AFTER LAPP & ANDREWS 1972 P 204)

Fig.1.2

the surrounding. Secondly it can travel through gases over a very long distance because it is lighter in nature.

Thus we have seen that the radioactive decay occurs in heavy unstable to stable elements and that the spontaneous decay rate is constant and accompanies by the emission of radiation. Further from the second equation of both α and ß-decay it is clear that some amount of energy is released.

Now it is known that alpha particle are characterised by discrete energy levels. The question then arises as to whether α-particles pre-exists in the nucleus and are emitted at appropriate times. Alpha particle substructures probably exist in the light nuclei which exhibit periodic properties. This however, does not appear to be true of heavy nuclei. There is a possibility that α-particles are formed first and are then emitted. If we set up a model that α-particle are in constant thermal motion with mean velocity of about 10^9 cm/sec. it can be shown that the α-particle can traverse the nucleus 10^{21} times/see. In the case of ^{238}U it would take 10^{38} attempts for an α-particles for one escape whereas 10^{14} attempts are adequate for escape in the case of α from $^{212}P_o$. This would explain the differences in the probability of α-emission in respect of the two nuclides. The greater the energy of the α-



ENERGY SPECTRUM OF β PARTICLES EMITTED BY 40K. NOTE THE HIGH PROBABILITY OF EMISSION OF β WITH ENERGY OF ABOUT 0.45Mev.

(AFTER FAUZE 1977, P-27)

Fig.1.3

particle the greater is its ability to cross over the potential barrier.

The heavier the isotope the longer is its half-life. This regularity however disappears around the magic number N126. The half life for α-decay is generally longer for even Z-odd N, odd Z-even N, odd Z-odd N. nuclides relative to even Z even N nuclide [Aswathanarayan, 1985].

From the second equation of the ß-decay. Pauli proposed the existence of the particle, neutrino, which is always emitted along with ß and shares the total energy packet. The neutrino has an incredible penetrating capacity it can go all the way through the earth and can penetrate a shield of lead one light year thick. It has no charge and no, mass but only energy.

ß-particles are characterised by a continuous energy spectrum. The maximum energy is called the End Point energy or Em.-Figure

1.4 THE NECCESSITY OF RADIOACTIVE WASTE DISPOSAL

Man's efforts to master the nature are largely based on his ability to control and develop various sources of energy. Since the down of civilization man has been growing more and more energy hungry. Till the beginning of the industrial age mother earth was able to easily support the energy needs of her population without much strain. In the past two centuries man has depleted the natural energy source at such a breath taking speed that the reserves of coal, oil and gas are fast coming to an end. In man's search for the alternative sources of energy the nuclear energy is an important landmark.

During the past 45 years the nuclear technology has come a long way since Fermi's first atomic pile went critical in Chicago in 1942. This was the event that demonstrated that the nuclear energy could be used for production of explosive material and generation of heat. Since then, the world has seen nuclear technology being applied primarily to two areas - weapons development and generation of electricity. There are other area also like cancer therapy medical and industrial x-ray imaging, food irradiation etc. All the above and other applications of nuclear substances matter us face the fundamental question of how safe the nuclear technology is ?

While conventional safety issues applicable to any technology are equally applicable to this field too, only one aspect, i.e., "radiation" has been predominant in the public's perception of nuclear technology. The principal cause for this is the fact that human senses do not react to radiation. One cannot see, hear, smell, taste or feel them while with almost every other human activity we can make a reasonable judgement based on common sense and without much of external advice as to how safe it is, with radiation it is not so.

Fortunately, nuclear technologists have always been aware of this and safety has always predominated all areas of nuclear technology. In all stages of nuclear technology evaluation of a particular activity includes quantitative assessment of the possible scenarios so that sufficient safety features are incorporated during the stages of design, construction, operation and maintenance.

Radiation emitted by radioactive nuclei are normally referred to as ionizing radiation in view of their ability to create ions in the matter in which they travel. The term ion is used to denote atoms or group of atoms carrying electrical charge [Atomic Energy of India, 1988].

Ionizing radiation cannot be felt by any of the senses of body. In sharp contrast heat and light which are other forms of radiation can be sensed by human body. The different types of ionizing radiation are :

i) High frequency electromagnetic radiation - x-rays and gamma rays.

ii) Stream of charged particles - alpha beta and protons and

iii) Stream of neutral particles - neutrons.

The penetrating power of ionizing radiation is varies with the type of radiation such as α-radiation can be stopped by a sheet of ordinary paper, whereas β-particles requires a few millimeters of aluminum sheet for stopping them. Γ-particle and neutrons are highly penetrating but can still be shielded by a thick block of concrete slab or water. X-rays are normally less penetrating than Γ-particle.

Similarly the effect of radiation has been exhaustively studied, researched and documented. There is an enormous amount of literature about this subject. There is also a powerful network of international and national organisations for its supervision and control, e.g. Department of Atomic Energy, Atomic Mineral Division.

Thus one of the aspect for the control of this radiation generated from the radioactive waste is to dispose these waste in suitable geological and oceanic environments. The overall objective of the radioactive waste disposal is to dispose of the waste in such a manner that there is no unaccetable detriment to man's environment. The isolation of waste from man's environment by the disposal system should remain effective until the radionuclides have decayed to an acceptable level.

The selection for the waste disposal site require a knowledge of a number of disciplines. These includes many branches of earth science, engineering, safety analysis, health physics, ecology economics and social sciences.

Evaluation of a waste repository rock formatin calls for the application of hydrogeological, scismological, geochemical studies.

CHAPTER - II

2. CATEGORIES and CLASSIFICATION OF RADIOACTIVE WASTE

There are many categories of waste which generally are defined on the basis of concentration, the radioactivity and radiotoxicity levels, the physical form and the half lives of the radionuclides involved. Wastes also arise from the various parts of the nuclear fuel cycle such as fuel fabrication plants, reactors, fuel storage facilities and reprocessing plants etc. waste also arises in small quantity from the production of radioisotopes and their use in medicine, industry and research. In spite of all that the radioactive waste are classified from the view point of disposal concept.

The general characteristics of waste categories based on which various radioactive waste are defined, and finally disposed of in suitable geological condition described below.

Table 2.1

WASTE CATEGORY	IMPORTANT FEATURES
I. High level long lived	High ß / Γ Significant α High radiotoxicity High heat out put.
II. Intermediate level long lived	Intermediate ß / Γ Significant α Intermediate radiotoxicity Low Heat Output.
III. Low-level long lived	Low ß / Γ Significant α Low/intermediate radiotoxicity Insignificant Heat Output.
IV. Intermediat level short lived	Intermediate ß / Γ Insignificant α Intermedate radioxicity Low Heat Output.
V. Low level short lived	Low ß / Γ Insignificant α Low radiotoxicity and Low Heat Output.

2.1. **SPENT FUEL:** (Category - I)

If the nuclear fuel cycle is chosen the spent fuel is not reprocessed and is considered to be waste. This waste is solid and in the same form as the original fuel. All the radioactivity present in the spent fuel remains in the waste. This high level of radioactivity includes that from the fission products and the transuranic actinides including all the plutonium. In addition, the unfissioned uranium and the gaseous fission products are contained in the waste. The spent fuel emits high levels of heat which requires special provision for cooling.

Following are the general characteristics of waste categories on which the various Radioactive waste are defined and finally disposed of in suitable geological condition.

Table 2.2

WASTE CATEGORY	IMPORTANT FEATURES
High-level long lived	High ß/r, significant α High radiotoxicity High heat output.
Intermediate level long lived	Intermediate ß/r Significant α Intermediate radioxicity Low heat output.
Low-level long lived	Low ß/r Significant α Low/intermediate radiotoxicity Insginificant heat output.
Intermediate level short lived	Intermediate ß/r Insignificant α. Intermediate radiotoxicity Low heat output.
Low-level short lived	Low ß/r Insginificant α Low radiotoxicity and Low heat output.

2.2. HIGH LEVEL LIQUID WASTES FROM FUEL REPROCESSING:

(Category - I)

This type of waste is the aqueous liquid remaining after the fuel has been dissolved and the uranium and plutonium have been extracted. It contains nearly all of the non-volatile fission products as well as almost all the actinides in the irradiated fuel other than uranium and plutorium. The portion of plutonium and uranium in the waste are generally between 0.05 and 0.5%. [IAEA , 1981]. In addition various quantities of elements such as iron, chronium, nickel, aluminum zirconium and magnesium are also present.

This waste is characterized by very high gamma radiation levels, large heat output and the presence of long lived actinide nuclides. The possible separation of the actinides from this waste has been taken into account and if separated the actinides could then conceivably be transmuted by nuclear processes in nuclear reactors or in other nuclear devices. [IAEA,1981].

2.3. **INTERMEDIATE LEVEL WASTES:** (Category II and IV)

Intermediate level wastes comprise of a variety of waste whose radioactivity levels are between high and low. They are generally produced in the fuel cycle by the following processes.

- -air filters
- -ion-exchange resins from reactor coolant clean up
- -ion-exchange resins and filter sludges from fuel element pond water clean up chemical sludges from liquid effluent floe treatment processes.

-evaporator concentrates

-liquid wastes from second and third cycle processing stages in fuel reprocessing.

-incinerator ash

-failed equipment

-decontamination chemicals

-general contaminated trash.

The characteristics radioactivity levels and hazards of wastes in this category frequently depends on the particular plant condition.

Most of the material in this group require shielding during handling and some wastes in this category may contain significant amount of long lived radionuclides or may require some cooling. [IAEA, 1981].

2.4. **LOW LEVEL LIQUID WASTES** (Category III and V)

Low level wastes can result from a number of liquid handling operations in a variety of nuclear facilities. They usually require no shielding during handling. The volumes can be large unless recycle of water within a plant is practiced to a large degree. [IAEA, 1981].

2.5. **ALPHA CONTAMINATED WASTES WITH LOW Β/Γ RADIOACTIVITY LEVELS:** (Category - III)

These wastes arise from fuel fabrication and can also arise from fuel reprocessing. They include

A variety of combustible trash
- gloves, plastics, rags, tissues etc.

Non-Combustiable material
- metal glass, ceramics, HEPA filters, failed equivalent and glove, boxes etc.

Solidified concentrates and sludges, derived from the treatment of certain liquide waste streams with low level of β/r radioactivity, containing significant amount of actinides.

The predominant hazard of these wastes is from the α - emitting nuclides rather than from associated fission products. It is possible that plutonium may be present in sufficient quantities to justify recovery.

2.6. **GASEOUS WASTES:** (Category II,III,IV and V)

These wastes arise from reactors, spent fuel and process plant off gases and ventilation. After appropriate treatment for removal of the radionuclides (e.g. by adsorption, scrubbing and filtration) the cleaned effluents are discharged to the environment. Iodine - 131 and Xenon-133 can be stored for a short period to decay. Iodine - 129 is currently removed from rector and reprocessing plant off gases and must be disposed of.

The longer lived 85_{Kr} is of importance primarily in reprocessing plants. It is currently discharged to the atmosphere eventually it is likely to be separated by adsorption or cryogenic processes followed by storage or disposal. Currently 14_{C} is being released to the environment but in future it may require separation fixation and disposal.

2.7. **LOW-LEVEL SOLID WASTES:** (Categories III and V)

This type of waste comprises a very large volume of combustible and non-combustible trash arising from reactors. Much of this waste is virtually non-radioactive but because it is potentially contaminated it sometimes assumed to be radioactive and is handled as such.

2.8. **Tritium-Contaminated wastes:** (Category IV and V)

Tritium is generated by fission in reactors where it is mainly related in the fuel or cladding and by neutron activation of both deuterium is heavy water and additives or impurities in other coolant e.g. boron and lithium in PWR currently it is not trapped after release from the fuel but is discharged mostly in the low level liquid effluent, the total volume of which is considerable.

2.9. **Decomminssioning Wastes and Contaminated Soil:** (Categories II, III, IV and V)

Decommissioning wastes and soil that may have been contaminated constitute a class of solid waste for which some conditioning has to be considered. All material equipment and parts of a nuclear facility that resist decontamination or in which the radioactivity will not decay to acceptable levels in a reasonable time, will eventually remain as waste for disposal. Some of the wastes from reactor decommissioning will contain radionuclides induced by neutron activation and will therefore radioactive throughout the bulk of the material. Decommissioning wastes also include the chemical solutions used to decontaminate materials for decommissioning. Most decommissioning wastes contain relatively low levels of radioactivity.

CHAPTER - III

3. WASTE TREATMENT, CONDITIONING AND PACKAGING

The objective of the waste treatment and conditioning are to reduce the volume and/or immobilized the waste in order to improve the conditions for handling in transportation, storage disposal. In the case of the failure of other engineered and natural harriers radionuclides in the waste will be released only at low rate.

Treatment technique can he categorized into two general groups.

3.1. WASTE TREATMENT

3.1.1. Compaction

Compaction is a mechanical technique used for volume reduction to facilitate waste handling, packaging and disposal. It increases the structural stability of the waste by increasing their density and it may reduce the dispersability by decreasing the surface area of the waste. [IAEA, 1985].

Volume reduction factors depend on the pressure applied and the waste material treated, in general they range between 3 and 10. The large contaminated items that cannot be compacted require the use of some other size reduction technique such as cutting.

3.2.2. **Combustion**

Combustion is an efficient method for volume reduction of the waste that contain combustile material. Combustion can eliminate organic matter from the waste a source of potential stability problem. It can also produce inert waste which can be subsequently conditioned to obtain a stable, leach resistant product. Combustion includes incineration, microbiological fermentation and chemical digestion.

Volume reduction factor upto 100 prior to conditioning can be achieved for many types of combustible waste for including items such as trash, spent organic resins, paper, animal carecasses and organic solvent.

Conditioning is intended to improve waste characteristics such as structural stability. Chemical durability, radiation stability, and resistance against microbial attack and gas generation and includes the incorporation of solid or liquid wastes into some sort of solid matrix.

Solidification is the conversion of liquid or semi-liquid material into a solid, and is considered a form of conditioning. When applied to liquid waste such as evaporator concentrates, slurries and sludges or other waste materials containing free liquids. Conditioning is most beneficial for highly despersable ILW such as incinerator ash or liquid wastes.

Desirable characteristic of the conditioned waste are:

(i) Stability against chemical mechanical, thermal, radiation and biological degradation

(ii) Non-combustibility

(iii) Low solubility or leachability into the ground water

(iv) Dust free state and freedom from the surface contaminate minimum practical volume.

(v) Safety from nuclear criticality

Appropriate packaging for handling and transportation.

3.2. WASTE CONDITIONING

The conditioning technology for the waste can be summarized below with respect to the general categories that are mentioned above.

3.2.1. **Spent Fuel** (category I)

Technologies are being developed for conditioning of spent fuel for disposal. From experience in some countries it is suggested that after suitable period in storage to allow shorter lived radioactivity to decay, the fuel may be encapsulated in metal or ceramic containers either as a whole or after disassembling it into fuel pins.

3.2.2) **High Level Liquid Wastes and their Solidifaction** (category I)

Before the technique is mentioned for the conditioning of these waste it is important to mention the differences between the spent fuel and solidified high level waste. The former contains about 200 times the quantity of plutonium and uranium, and exhibit significant heat generation rates over a longer period. The plutorium content primarily influences the long term hazard, while the uranium content primarily influences the waste form and volume and has some influence on the very long term hazards.

It is generally agreed that a high level liquid wastes should be immobilized by conversion to the monolithic solid for greater safety during interim storage and in transport and disposal.

3.2.3. **Intermediate Level Waste** (categories II and IV)

A variety of methods for conditioning these materials are available. The immobilization method usually used are as follows: [IAEA, 1983].

i) concrete of various compositions
ii) ploymer impregnated concrete
iii) bitumen
iv) thermosetting plastic resins (polyster epoxy)
v) thermoplastic resins (polyethylene)

Each of these techniques has different characteristics and the choice is to be made in relation to the particular waste and the specific disposal system under consideration. In some cases it will be sufficient if the wastes are packaged into containers after dewatering without any conditioning. In others a waste can be directly disposed of without packaging in the form of a self-solidifying slurry.

3.2.4 **Low level Liquid Wastes and their Solidification** (categories III & IV)

Treatment of such waste consist of processes such as precipitation, ion-exchange, distillation, sorption, solvent extraction or filtration. In many cases the cleaned fluid can be discharged into their environment and the residues are then immobilized and packaged for disposal.

3.2.5 **Alpha Contaminated Wastes with Low ß/Γ Radioactivity Levels**: (category III)

Various processes for the conditioning and treatment of this type of waste are in use and other are being developed for oxidizing the combustible waste by incineration or acid digestion to reduce volume and a flammability, the resulting ash may be leached to remove plutonium. Such residue either can be incorporated into one of the matrix material such as concrete or could be converted into ceramic or glazed alumino-silicates, cement blocks,which can be canned for disposal. Alternatively these wastes may be added to the solids prepared from high level liquid waste or to the cladding hull and hardware waste. [IAEA, 1983].

Non-combustible waste could be decontaminated as far as practicable. Contamination of metal components can in some cases he reduced to very low level which could easily be disposed of with insignificant levels of α-radionuclides.

3.2.6. **Low Level Solid Wastes**

Low level solid waste either be packaged in steel drums by compression to minimize the volume or combustible waste may be incinerated with residue being immobiliged.

3.2.7. **Tritium-Contaminated Wastes**

The options for tritium contaminated liquid waste are-

a) dilution and direct discharge into the aqueous environment, including the oceans.

b) deep well injection

c) hydraulic fracturing

d) immobilization in a packaged solid and burial

e) deposition in a packaged and solidified form on the ocean floor.

Deep well injection, hydraulic fracturing or direct sea discharge may be considered for large volumes with low concentration of tritium. For more concentrated solutions of smaller volume, immobilization in a solid may be selected. The solid forms under consideration are cements with or without impregnation by polymer resins, silica gel. activated alumina, hydrated calcium sulphate molecular sieves, organic hydrogeneous compound and metal hydrides.

Many of these options would require containers designed to prevent contact with water or waste vapour with which the tritium in the solid waste could exchange. Storage of the immobilized and packaged wastes may be required, but disposal may also be implemented.

3.3 WASTE PACKAGING

The main objective of the waste packaging is to provide a containment & to some extent shielding of the waste during handling, transportation & storage. Packaging will improve the safety of disposal and also provide easy emplacement in the respository and will allow a more efficient use of the available disposal space.

The most important characteristic of the waste package should have the same desirable characteristic as the type of waste itself, which means it should he stable and resistant not only to physical impact during handling & disposal but also to internal effects such as gas generation, increase of volume due to the swelling of the organic resins, heat generation due to the decay of radioactive minerals etc. Secondly, the package should he easily transportable as well and should provide shielding against radiation. [IAEA, 1985].

Waste packages are Categorized as follows:-

3.3.1. **Wooden Boxes, Cartoons, Bundles, Plastic Bags etc.**

These containers are used for very low level waste of various types. The mechanical strength is poor & they are susceptible to damage caused by the weight of over lying wastes backfilling & trench cover deep-rooted plants, burrow animals organic decomposition & soaking by percoating water.

3.3.2. **Metal Drums or Containers with or Without Protective Coatings**:

These containers are suitable for most kinds of solid or solidified low level waste (LLW) & Intermediate level waste (ILW).

Their mechanical strength and the corrosion resistance are good. They may be acceptable for both shallow ground & rock cavity disposal. Their corrosion resistance depends on construction material and conditioning in the repository. Corrosion resistance can be improved by protective coatings oth inside and outside the container. [IAEA, 1985].

3.3.3. **Shielded Casks & Containers**:

These types of packagings are is used for their transportation of intermediate level waste. The whole container can be disposed of or the inside liner with the waste can be removed from the transport container for emplacement in the repository.

The inside liners are usually made of steel or concrete and exhibit good mechanical stability and corrosion resistance.

3.3.4. **High Integrity Containers**:

These package are used for transportation & could be used for disposal of dewatered low & intermediate level slurries, sludges & spent ion exchange resins & other waste requiring structurally stable packaging . The containers exhibit very good mechanical stability & corrosion resistance. They are leak tested & guaranteed. They can be disposed of in the facility & provide additional containment of the wastes.

3.4 EFFECTS OF RADIOACTIVE WASTE ON THE SURROUNDING ENVIRONMENT

The containment of radioactive waste is essentially imperative to protect the surrounding environment as well as the living beings.

It has now clearly been proved that any exposure to ionizing radiations i.e.., Γ and X-rays, neutrons α & ß particle over and above the naturals back ground levels involve some degree of risk to health. The effect due to radiation exposure are given in the following Table.

Table 3.1

EFFECTS OF WHOLE BODY RADIATION

Dose (rems)	Effects
0-25	A dose around 25 run way reduce the white blood cell count
25-100	Nausea for about 50% of those exposed, fatigue, changes in blood.
100-200	Nausea, vomiting, fatique, possibly fatal, loss of immunity (low white cell count).
200-400	A lethal dose for 50% of those exposed especially in the absence of treatment Bone marrow spleen(blood forming organs) damaged.
600	Probably fatal even with treatment

Radiation is generally expressed in the unit of rads which is an abbreviation for radiation absorbed dose. One rad is the amount of radiation required to liberate 1 x 10^{-5} J of energy per gram of absorbing materiel and rem is equal to one rad of X-ray or Γ-ray.

It is generally accepted that all radioactivity is potentially damaging to living matter but its effects will depend upon the activity of the source, their proximity the length of the time of exposure, the type of radiation and the tissue irradiated.

The levels of ionizing radiation associated with class I & II wastes could, if unshielded, severely affect human tissue, the gut and the central nervous system resulting in leukopaenia, purpura, haemorhaging, fever, vomiting & ultimately death.

The level of exposure to the natural background radiation will vary enormously from place to place accoding to the altitude, the nature of the rock the ground and river water and many other factors. Thus, it many not be appropriate to generalize on the extent of exposure in average terms.

Clearly the spent unreprocessed fuel (SURF) and reprocessed high level waste and other α wastes need to be contained in an environment which provides adequate shielding and isolation from man and biosphere generally while at the sametime being capable of absorbing and dispersing of the heat generated by the radioactive decay of the waste.

The ICRP has recommended a system of the dose limitation which has three main requirements. [Roxburgh, 1987].

1) That no practice shall be adopted unless its introduction produces a positive net benefit (justification)

2) That all exposures shall be kept as low as reasonably achievable, economic & social factors being taken into account. (also known as optimization of protection & the ALARA principle)

3) The dose equivalent to individuals shall not exceed the limits recommended for the appropriate circumstances by the commission.

Although it is not applied in all cases, NEA has also proposed a recommendation in the form of risk, where the risk is defined as the product of the probability of incurring a radiation dose & the probability of that dose giving rise to deleterious health effects. [Roxburgh, 1987].

CHAPTER - IV

4. DISPOSAL SYSTEMS

The safe disposal of radioactive waste which is the final step in the waste management operation chain is of vital importance for ensuring the long term protection of man and his environment. Although the disposal system in order to ensure isolation of the waste from the biosphere is a complex problem, the characteristic of each major component of the system are so varied that the strict generalized classification of applicable disposal options are not possible.

For the disposal purposes the waste as mentioned earlier are categorised in five groups such as. i. High level long lived

ii. Intermediate level long lived

iii. low level long lived

iv. Intermediate level short lived

v. Low level short lived.

Shallow ground disposal is suitable for low and intermediate level short lived radioactive wastes, mainly category V and possibly category IV, where as deep continental formation are suitable for the disposal of high level wastes with significant quantities of long lived actinide wastes such as category I. [IAEA, 1983].

Preferred disposal options for different radioactive waste categories are indicated in Table No.

Table No 4.1

Disposal options		WASTE CATEGORY				
		High level long lived	Intermediate level long lived	Low level long lived	Intermediate level short lived	Low level short lived
Emplacement in geological formations	Dry	Solid immobilized packaged spaced for heat dissipation	Solid, immobolized Packaged		Applicable but may be more stringout than necessary	
	Wet	As above possibly with more engineered barriers	As above; possibly with more engineered barriers			
Emplacement in mines or cavities	Dry	Not recommended	Possible depending on circumstances		Solid may be packaged	
	Wet	Not recommended			Solid immobilized packaged	
Emplacement at shallow depths	Dry	Not recommended			Solid immobolized packaged with more engineered barriers	Solid may immoboliz zed or packaged with more engineered barriers
	Wet	Not recommended				
Injection of self solidifying fluids into induced fractures in low permbility strata		Not recommended	May be possible with adequate demonstrated technology or certain radionuclides		Applicable with appropriate technology	
Liquid injection into deep permeable formations		Not recommended	May be possible with adequate demonstrated technology and certain radionuclides		Applicable with appropriate technology	

On the other hand the rock cavity concept can span the entire spectrum ranging from the categories II to V except category I having high level radionuclides having long half life.

4.1 DISPOSAL IN SHALLOW GROUND

Shallow ground disposal refers to the emplacement of solid or solidified radioactive waste near the ground surface at depth not exceeding a few tens of meters.

The option is considered suitable for disposal of low and intermediate level solid and solidified radioactive wastes that are short lived i.e, their radioactivity will decay to acceptable level within the time period for which institutional control of the reporitory site can be expected to continue.

Certain ILW and may have characteristic which prevent or limit their accetability for direct disposal in shallow ground in their original form. These waste may be made acceptable by suitable conditioning and packaging. If the waste form have unfavorable physical and chemical properties e.g. high leachability or high dispersability, then a site having superior isolation capability or a design having improved engineered barrier might be required.

Overall the important features for achieving radiological safety for shallow ground disposal include.

(a) favourable site characteristics and

(b) use of engineered barrier and appropriate waste conditioning.

There are a variety of potential designs and operational practice that may be combined to meet the basic requirement.

4.1.1. **Disposal Above the Ground Surface**

(i) The oldest and simplest method of shallow ground disposal is that of placing untreated solid waste directly on the earth's surface and later covering the waste with a layer of soil. The engineered barriers are minimal, primarily protection being provided by the packaging and by the sorption and mechanical properties of overlying and surrounding soil. [IAEA, 1985].

Erosion , intrusion by animals, percolation of rain water ground water movement and other process can adversely effect the safety of this method.

Relatively large areas are required under this method and it changes the appearance of the landscape. It is seldom used as a new repository for radioactive wastes because use of its safety implications.

ii) Radioactive waste are also disposed of under the earth covered mounds which are protected by various engineered structures.

iii) In some countries waste are combined with protective materials in monolithic blocks near the earth surface e.g. a concrete pit which may be additionally lined internally and/or externally to reduce precipitation and the entry of ground water is barred with solid wastes after which the free space is filled with a concrete mixture that may or my not contain radioactive concentrates. A layer of concrete is also poured over the top of the wastes. [IAEA,1983].

4.1.2. **Construction Disposal Beneath the Ground Surface**

iv) Disposal of radioactive waste in pits and wells: The emplacement of wastes into pits, and well dug in specific area and subsequently covered with a layer of soil. The advantage of this method is that requirement of somewhat the smaller area owing to the greater thickness of emplaced waste and the correspondingly smaller changes in the landscape.

v) Recent practice has been to locate the trenches typically above the groundwater level and sometime on a layer of clay or other material with low permeability andgood sorption characteristic. These trenches are lined with bitumen or other material to improve confinement. On the whole three basic engineering barrier are applied in order to prevent escape of the radioactive waste.

a) the most important material with low permeability above the trench to minimize surface water entering the trench.

b) a water diversion and drainage a system to direct water from the surface away from the trench and

c) a trench bottom with low permeability.

The system can be further protected from erosoin by planting vegetation or covering with rock rubble and by careful contouring of the final surface. The space round the trenches in turn can be filled with gravel or sand and other porous material to drain precipitation water away from the wastes.

4.1.3 Shallow Ground Disposal in the Indian Context

Disposal of radioactive solid wastes in shallow ground repositories has been in practice in India for nearly two decades. Experience gained in this period, varies from a small facility catering to the research centre at Trombay in the early sixties, to considerably larger repositories associated with the nuclear power programme at different sites in the country.

Different facilities of the Indian nuclear power programme and those related research and development centres are fairly wide spread around the country. Due to the vastness of the country these nuclear plant sites have diverse characteristics in respects of climate, geography and geographical parameters and requiring individual evaluation with regard to locating shallow land repositiories.

4.1.3.1 **Site Investigation Taking Geohydrological Conditions Into Accont:**

The geohydrology of the area is studied with particular reference to presence of water table, its depth and flow direction and velocity of subsurface water movement in different seasons of the year. These studies normally employ conventional techniques like bore well pumping and packer tests in addition to hydrological dynamics using tracers. [Nuclear India, 1986].

Due to varying conditions of geohydrology at different shallow ground repository sites in the country, it becomes necessary to study the sites and their specific features which would influence the development and design of repository at each site.

It has been noticed that all the three coastal sites viz. Trombay, Tarapur and Madras the movement of ground water is generally confined to the soil and weathered rock zones.

At the two sites on the western coast viz. Tarapur and Bombay which receive significant rainfall during monsoon the fluctuation in the water table is considerable while at the peak of the monsoon season the such surface water table may reach within a few cms of the surface, the drainage in the areas is very rapid to take the water table to a depth more than six meters below ground immediately after the rains and the drainage is generally towards the sea. [Nuclear India, 1986].

At Narora the sub surface water is associated with an extensive unconfined aquifer which normally prevails at a depth of six to eight meter below the surface. This acquifer get drained into and recharged by a series of irrigation canals and the nearly river Ganga. [Forty Years of Atomic Energy of India, 1988].

In contrast, the repository site in Rajasthan no ground water is encountered up to considerable depth. Any such surface water movement is only due to precipitation which percolate through the highly fissured sandstone formation and here also the drainage is very rapid into a nearby lake. [Annual Report, 1988].

Due to the climatic condition with moderate to heavy rainfall in many of the repository sites our experience indicate that management of surface water flow is extremely important. Failure to provide adequately sized drains for surface water flow would result in flooding of waste trenches. [Annual Report, 1987].

4.1.3.2 **Design and Development of Shallow Ground Repositories**:

The concept of design and development of shallow ground repositories has undergone a steady evolution. Some of the major factions which differentiate our current approach is as follows:

a) Establishment of an adequate buffer zone between the operational areas of the repository and the external boundary of the repository.

b) Clear isolation, even at the design stage, of administrative and support facilities from the operating areas of the repository.

c) Provision of facilities that may be required to segregate the wastes and repack/overpack the wastes when required.

d) Provision of area and equipment for purposes of decontamination

Models that are usually practiced in india:
[Nuclear India, 1986].

In general three types of disposal models have been practiced in india

i) Unlined earth excavations

ii) reinforeed cement concrete trenches

iii) Steel lined concrete tile holes

While the unlined earth trenches are utilised only for wastes with suspect contamination; the other two disposal models are used for radioactive solid wastes with significant contamination.

4.2. DISPOSAL IN ROCK CAVITIES

Waste disposal in rock cavities refers to emplacement of wastes in different types of cavities located at various depths from just below the surface to deep geological formations. In principle the rock cavity disposal concept is an approach between the options commonly called shallow ground disposal and disposal at deep geological formations. It involves the emplacement of solid or solidified LLW and ILW in existing man made or natural cavities e.g. abandoned mines or in cavities especially excavated for waste disposal. These different kinds of cavities may be sited in different geological formations and located at different depths, ranging from relatively near surface to depths typical for deep geological disposal. Although the depth of the repository is an important factor, it is not an essential parameter, since the isolation capability of the total systems is the most important consideration rather than the performance of any one component.

In principle waste in categories II, III, IV and V may be disposed of by this method. Depending upon the degree of isolation provided by the overall disposal system, institutional controls may not be required after the operational period has ended.

4.2.1 **Types Of Cavities**

The cavity in a geological formations of potential interest for the purpose of disposal of solid and intermediate level radioactive waste can be of different kinds and located at various depths. These are

4.2.1.1 **Specially Excavated Cavity**

The specially excavated cavity can be developed in different geological formations at various depths depending the waste characteristics and the engineering methods utilized to improve the waste isolation. These cavities for the disposal of radioactive waste can be constructed in geological formations using mining methods determined by site requirements.

Specially excavated cavities have certain advantages over natural caves and disused mines and they are listed below:

-flexibility in design (choice of depth, orientation, size shape

-increased probability that no unknown bore hole exist

-absence of ore bodies

-no unnecessary shafts, tunnels, vaults or caverns required

-location can be chosen on the basis of reducing transport risks and costs.

-Socio economic and socio political consideration can be part of siting processes.

-Construction technique can be chosen to improve repository safety and efficiency

Possible disadvantages are

-lack of suitable work force and their accompanying infrastructure.

-more costly in that all underground space must be newly created.

-need for in situ information on the geotechnical and

-hydrogeological properties of the repository

Before the development of the repository it is necessary to carry out geological, geochemical hydrogeological, geomechanical, geophysical and special engineering investigation.

Repository cavities for the emplacement of waste can have various shapes and volumes which depend on the planned disposal methods. The shape of the repository can be in their form tunnels, vaults, vertical cylindrical caverns, or some combination of these.

4.2.1.2. **Disused Mines and Other Cavities**

Disused mines were once used for exploitation of various ores.

A suitable access to a potential repository may already exist in the form of mine addits or shafts. The length of access may vary from several hundred to several thousand meters depending upon the original mining circumstances. In some places the shaft will pass through water bearing zones which might require special engineering works such as relining with concrete steel or other materials in addition to grouting. [IAEA, 1983].

There could also be a variety of other openings which were connected with the original minning operations e.g. stopes winzes raises and ventilation shafts which could be of interest for waste disposal.

4.2.1.3. **Natural Cavities**

It is highly doubtful that any natural cavities large enough for human entry will be utilized for a waste repository as they are generally wet or have an acethetic value or are protected as natural phenomena.

Two kinds of natural cavity could be of some interest for the disposal of low and intermediate level radioactive wastes. The more important of the two is the type of primary caves formed in volcanic lava formations known as lava tubes. Most such caves are long narrow passage which may be from a few meters to a few kilometers long. The wall of these cavities may be fractured within the possibility of these fracture being the pathways for groundwater flow.

The second kind of natural cavity is comprised of secondary cavities which were formed through dissolution of the carbonate rocks by flowing groundwater. These caves are most abundant in lime stone and dolomites. In some regions these cavities are generally wet and contain flowing water. Such cavities could be very large in size and their length could sometimes be up to a few tens of kilometers. Rarely in such large cavities a section of the caves located above the water table might be suitable for the disposal of low and intermediate level wastes. [IAEA, 1983].

4.3 DISPOSAL IN DEEP CONTINENTAL FORMATION

For high level and α - bearing wastes resulting from the nuclear fuel cycle, the leading concept in most countries is disposal in deep stable geological formations. The function of such type of disposal is to provide primary barriers for controlling possible radionuclide releases from the emplaced waste into the living environment so as to keep them at permissible levels.

Following are the general criteria for the disposal of HLW in deep geological formations. [IAEA, 1981]

a) The geology of the region should be investigated beyond the repository zone so as to permit an effective evaluation of the targeted repository formation.

b) The waste should he emplaced deep enough so that they will not he laid open by natural processes while their radioactivity level is unacceptably high. Possible future climatological changes should be considered.

c) The geological medium in the zone of waste emplacement should be sufficiently thick and extend far enough laterally to provide an adequate protective zone around the repository. Such a zone a would assist in providing an adequate degree of separation from underlying and overlying strata and flanking transition zones and faults etc. This criterion is important in most disposal concepts particularly for emplacement of fluid waste into porous permeable strata.

d) The geological host medium and its surroundings should he geologically stable and in a region where continuing geological stability for the period of concern is anticipated.

e) The excavated zone exploratory test holes should be backfilled and/or sealed in such a manner as to ensure that the migration of the waste constituents to the human environment in satisfactorily limited.

f) The repository should be in location which is not foreseen to be of interest for future exploration in a manner that could reduce the integrity of the waste confinement.

g) The hydrological character of the geological environment should be compatable with the waste forms to be emplaced. In general the hydrogeological character of the entire geological environment should be such as minimized to the water flow past the emplaced wastes.

h) The underground repository should be constructed so as to cause negligible undesirable change to geological environment or to effects its hydrological characteristics.

i) Possible undesirable chemical reactions of the groundwater with the conditioned waste first with the packaging and then with the immobilized waste itself should be considered. A possible increase in the corrosiveness of the groundwater due to products of radiolysis should be allowed for when choosing waste packaging materials.

j) Retardation of the potential migration of radionuclides through interaction with underground natural or installed materials should be considered.

k) The engineered structures and geological strata should be capable of with standing and effects of the radiation and heat generated by the wastes.

l) The repository should be designed so as to the possible creation of wastes migration pathways by failure of engineered structures.

CHAPTER - V

GEOLOGICAL/GEOPHYSICAL INVESTIGATION FOR SAFE DISPOSAL OF RADIOACTIVE WASTE

Following are the major earth science criteria for selecting the disposal of radioactive waste from the viewpoint of geological considerations.

5.1 CLIMATOLOGY

The type and amount of precipitation will influence the amount of surface erosion, the occurrence and depth of groundwater, leaching and transport of radionuclides from waste material and the rate of evapotranspiration in the area. Wind direction and velocities are also taken into account because of their influence on erosion.

Annual precipitation can range from negligible precipitation in arid regions to more than 1000cm in very humid regions. Variation in precipitation with time are more noticeable in the semi-arid and arid regions than in the humid regions. 'Annual precipitation does not vary in a completely random manner, but neither is there a high degree consistent precipitation. Long-term records of precipitation, have the appearance of distinct cyclic variations, but thus far none seems to fit any specific cycle.

Area with humid climates generally lack a significant depth of unsaturated strata above the water table have short ground water paths to surface water and are prone to surface flooding, but they have relatively high evapotranspiration rates due to thick vegetation. Arid climate on the other hand may have deep water tables with extended subsurface flow path to surface water, low frequency of flooding and very reduced evapotranspiration rates. Thus arid climates are in general, move favorable than humid climate for shallow ground repositories. [IAEA, 1982].

Much of the surface water and near surface soil moisture is evaportranspired at a rate varying with temperature, density and type of vegetation cover and the availability of moisture.

Evapotranspiration rates vary considerably with season and location. Summer evapotranspiration in northern latitudes ranges upto 80% or more of the annual total, whereas in subtropical latitudes the summer evaporation frequently constitutes less than 60% of the annual total. Although other factors are important in evapotranspiration, temperature has a major effect, with high temperature contributing to high evapotranspiration rates.

5.2 TOPOGRAPHY

Topographic factors that affect the surface hydrology of a site are: [IAEA, 1982].

i) size of the contributing drainage area.

ii) shape of the drainage area.

iii) gradient of the land surface,

iv) density of the drainage network, and

v) slope of the major stream channels

Accurate determination of the effects of each of these factors on surface hydrology is nearly impossible because of interaction among factors and the virtual impossibility of separating the effect of one from the others.

Area with topographic extremes could give rise to difficulties for a shallow ground repository because they limit the types of engineered repository facilities that are applicable and increase the potential for erosion. Steep slopes limit the size, orientation and accessibility of disposal trenches or may even prevent trenches from being used. Such areas may also increase the potential for accidents in the transport of waste and may increase the cost of constructing and maintaining railways and roads to the repository. [IAEA, 1982].

If major earth moving is to be carried out to modify the land surface for better accommodation of a repository, it is essentiall that due consideration be given to any changes in the rate of erosion or surface run off that might ensue.

In some cases, changing the topography may increase the local rate of water infiltration resulting in a rise in the water table which could increase possibility of the ground water contact coming in act with the waste.

5.3 GEOLOGY

The safe disposal of radioactive waste requires that the geological environment of the areas be favourable. The safety of the waste repository is highly dependent upon the engineered barriers and the characterestics of the natural geological formations that act as barrier to radionuclide transport.

These natural barriers include the capability of geological environment to minimize contact of groundwater with the waste and its capability to sorb and retard the movement of waste constituents. Additional barriers may be-provided to enhance the natural barrier by conditioning the waste and/or by application of other engineered feature.

These man-made barriers should be compatible with the natural barriers. [IAEA, 1982].

Following are the general geological factors which are essential for the safe disposal of radioactive waste beneath the ground.

i) Erosional and superficial processes.
ii) Size and shape of the specific body
iii) Geometry, physical, chemical and mineralogical properties.
iv) Structurally stable criteria.
v) Tectonic and seismicity.
vi) Free from Fault.
vii) Abonarmally high geothermal and volcanic activity.
viii) Mechanical, geophysical and state of stress.
ix) Backfilling, sealing and natural barrier.
x) Unchopped and Unprocessed material should be avoided.

5.3.1 **Erosional and Superficial Processes**:

The disposal should be at such a depth that it should beyond the reach of erosional, surfacial weathering as well as the superficial processes. Most surface and near surface forces or phenomena are confined to shallow depths. However, in some instances their could be deep erosion, if considered over a very long period, thereby endangering the repository. One could cite examples of glacial ice or fast eroding rivers in areas of active tectonism. Thirdly, the effect of a major meteorite impact or the largest man made explosions at the surface would penetrate to a depth no greater than 100m although fracture may extend beyond this depth. Thus the geological location and the depth of the repository chosen should be such as to eliminate it from possible accident.

5.3.2. **Size and Shape of the Specific Body:**

Shape of the prospective host bodies of rock should be divided into two major classes

a) Tabular or stratiform and

b) Equidimensional to irregular

a) Tabular or stratiform bodies include sedimentary rocks, volcanic flows, igneous sills commonly occurring as horizontal or gently inclined succession. Hydrological transmissivity of waste flow through this non uniforum (anisotropic) rock body may be significantly greater parallel to stratification than across it. Thus disposal in tabular body would commonly require special consideration.

b) Equidimensional and irregular body may include a variety of igneous intrusion including plug dome, or diapirs of gypsum, anhydride, mud or salt such isotopic body with respect to transmissivity and other pertinent properties would require appropriate shapes of buffer zones and buffer envelopes.

5.3.3. **Geometry, Physical, Chemical and Mineralogical Properties**:

For the disposal of radioactive waste information on the geometry, physical, chemical and mineralogical properties of he prospective host rock body and the associated rocks is required. Such borehole would be utilized for in hole geophysical logging and perhaps measurements and test of other characteristics. However, each borehole presents a danger of subsequent leakage of fluid and of weakening the mechanical integrity of the host body and surrounding rocks especialy as the rock is heated. The number of exploratory and test bore holes can be minimized by the use of non-penetrative geophysical techniques such as multi-channel seismic reflection are currently in the experimental stage and show much promise. [IAEA,1982].

5.3.4 **Structural Stablity Criteria**:

The disposal should be within the structurally stable geological block and not near a tectonic boundary. The boundary of the block are where stress concentrations could occur that might open fracture that would change the conditions in that marginal zone. Rates of the geological movements are small differential movements between blocks and may range from essentially zero to a few centimeters per year.

Diapirism is the upward intrusion of material that is plastic under pressure such as rock salt or clay. The rate of diaprism at the site which can be influenced by mechanical, chemical and thermal stresses in the rock resulting from the construction and operation of a waste repository must be low enough so that during the required period of isolation the waste will not reach a location where the containment might be breached by either fracture flow or solubility. The required period isolation extends through the period during which the radioactive waste presents unaccetable hazard to the biosphere.

5.3.5. **Tectonics and Seismicity**:

A region that has been and/or is currently tectonically active may be characterized by contorted strata dislocated by a dense network of fractures and joints. The presence of the major fault frequently indicates a line of structural weakness and can be a principal pathway for groundwater to move, thereby reducing the capacity of the ground to confine the radioactive waste. [IAEA, 1982].

Very often movements are discontinuous giving rise to seismic events e.g. earthquakes where the gradual build up of stress in geological strata is suddenly and catastrophically released as a movement of some areas relative to contiguous areas. In Other cases very slow readjustment such a subsidence or uplift of the surface may be taking place and will continuously modify erosional or depositional processes. In areas of very a active tectonics uplift or subsisdence of the ground could occur in the near future and modify the erosional processes and the surface and ground water regimes. Recent tectonic deformation experience by sedimentary formations, recent faulting, or modificatiions in the geodetic data can indicate general instability of the area in the past, present and future.

An earthquake could conceivably damage the engineered or natural structure of the repository provoke collapse or failures of the confining barriers and thereby increase the potential rate of migration of the waste back to the surface. Earthquake can also produce fissures and faults in the geological formations, such features could possibly impair the site capacity for confinement by increasing the permeability of rocks or by modifying the water table elevation and characteristics ground water flow. Seismic activity can also trigger landslides and thereby modify topography and can significantly modify the surface water and the ground water regimes.

For these seasons, areas of high seimicity and those in the immediate vicinity of active faults should be considered unfavorable for the disposal of the radioactive waste.

5.3.6 **Avoidance of Fault:**

Faults that are seismically active or for which there is geomorophological evidence of slip during the last millions of years of the Quarternary period can be expected to move again and possibly within the lifetime of the disposal [IAEA, 1982]. The movement along the fault may unpredictably change the estimated value of the parameter of containment therefore a repository should not be placed in such location.

Seismic shaking is not a significant problem in the design of underground working although the meteorite impact and scale man made explosion could destroy surface installation.

5.3.7. **Abnormally High Geothermal and Volcanic Activity**:

Igneous activity is not a random process but is concentrated along the active tectonic boundary or above so called geological hot spot. An area that has experienced volcanic activity in the Quarternary Period is likely to have further activity in the future. Thus the area with abnormally high geothermal gradients or with evidence of relatively recent volcanic activity are possible candidates for future volcanic events and should be avoided.

5.3.8. **Avoidance of Mechnanical geophysical and state of stress**:

The facility must remain open at the operation temperature without failure or collapse during the period of active operation. The design of excavated values and the spacing of passage way should be such that the maximum stresses resulting from the cavities, thermal stress and inherent state of stress in the wall rocks should be well below the critical value of the uniaxial compressive strength of the rock.

5.3.9. **Intactment of Backfilling, Sealing and Other Natural Barrier**:

Backfilling and sealing of the cavities would inhibit ultimate roof collapse and prevent subsidence fractures which propagate from the repository vaults and tunnels through the host rock and possibly breaching the containment of the repository.

5.3.10. **Avoidance of Unchopped and Unprocessed material:**

Introduction of unchopped and unreproced spent fuel elements for retrievable storage into a respository used for the permanent disposal of radioactive wastes creates complications that could be avoided. These could include the potential problems of leakage of volatile radionuclides, increased geochemical interactions with host rock and the contradictory design and operation requirements for both permanent disposal and temporary storage of wastes. The potential rates of escape of radionuclides to the bioshpere would be significantly higher, than the rates characteristics of waste that had not been chemically processed for optimum stability. [IAEA, 1984].

5.4 **HYDROLOGY**

The principal natural means for the potential transfer of radioactivity away from the repository into environment is by water flow, either from surface water or from groundwater. Thus a good knowledge of the characteristic of the water system in the immediate vicinity and in the area around repository is essential in order to assess the confining capacity of the site. [IAEA,1982].

5.4.1. **Surface Hydrology**

It is very important to understand the stream and lake networks in the vicinity of repository site and to know their characteristics, such as flow rates and to levels at different periods of time.

This knowledge of the surface streams lakes, ponds, swamps etc. is necessary for many reasons, which usually includes one or more of the following: [IAEA, 1982].

-Evaluation of the flooding potential.

-Evaluation of the potential of erosion and sediment transport and possible changes in river channels.

-Identification of the recharge and discharge areas for the underlying aquifer.

-Evaluation of its use as a resource to man.

Knowledge of the flows of surface water is needed to define the ground water balance which in turn, is needed to analyse the potential for the undesirable entrance of water into the repository. In addition, because surface water constitute important monitoring points around the repository, knowledge of their systems is needed to properly evaluator the data from monitoring.

Surface waters are likely recipients of possible releases of radionuclides from waste repositories and they provide locations for disperation of materials throughout the environment. They also produce the possibility of dilution of radionuclides that might have been released from a repository [IAEA, 1982].

For sites along a large lake or seashore, consideration should also be given to the potential for flooding as a result of tsunamis seiches or tidal waves. The circulation of water flow currents may also need to be understood if waste constitutes could reach an estuary or sea is relatively high concentrations.

5.4.2 **Hydrogeology**

In nature there are no known region where the ground is devoid of liquid water.

In arid areas it is possible to find closed hydrogeological system is which the hydrological balance is at steady state i.e., the evapotranspiration balances the water supply so that here is no lateral flow of water and no outlet except towards the atmosphere such situations are generally advantages for shallow ground disposal [IAEA, 1982]. However, it may be difficult to predict climatic changes and consequently the stability of the system for the period of concern.

Most prospective waste disposal area will generally have one or more known acquifer that could possibly allow for transport of radionuclides towards the natural or artificial outlets of these aquifers. Even clays normally regarded as impermeable have a finit measurable permeability [IAEA, 1982].

The long term stability of the conditions of the partially saturated zone and the ground water must be considered for the period during which the waste remains a nuisance, This stability can be influenced by factors such as changes in climatic conditions changes in the regional level of streams which can produce a modification of erosion rate, artificial modification of the stream regimes resulting from the channeling rivers building dams, increased water abstraction etc.

It is easier to predict the movement of groundwater for homogenous strata with an intergranular porosity than for fractured rocks. Safely analysis and monitoring are consequently easier to perform and are more reliable in the homogenous strata. Thus from this standpoint, favourable strata are those with low permeability and which are homogenous.

Favourable geohydrological conditions for a repository would in general, include a homogenous formation of low permealibity with an indivdualized and limited groundwater system, having no connection with other aquifers and having a limited number of well known outlets that are easy to monitor and control.

5.5 GEOCHEMICAL CRITERIA

It is important to consider the geochmeical factor when a waste repository site is selected and a repository is constructed, because the geological properties and reactions of the radionuclides determine their mobility between the initial site and the biosphere.

Following are the some important criteria in this regard: [IAEA, 1982].

i) Radioactive heat and radiation factor

ii) Interaction of water with repository rock.

iii) Chemical and physical reaction of water with the repository and

iv) Properties of the geochemical system of the radionuclide, the repository rock, and its associated water.

5.5.1 **Radioactive Heat and Radiation Factor**:

The thermally induced geophysical processes remain within the predictable limits, an upper operating temperature should be prescribed for every combination of the repository rock type the waste form and composition for the operating life of the repository.

Over a period of hundreds of years, the radioactive heat will accelerate diagnetic reactions that will affect the rock properties such as porotisty porewater volume transmissivity, exchange capacity, ion retardation, rock volume and thermal diffusivity.

Finally the radiation induced distortion of the crystal lattices of minerals will generally increase their solubility and decrease their thermal stability but its physical and chemical effects will be minor.

5.5.2 **Interaction of Water with Repository Rock**:

The choice of the form of the waste, its container the properties of the specific host rock, the composition of the available water, the ambient temperature and pressure the nature of the any internationally added materials and the equilibrium constants of he possible chemical reactions define a complex interacting chemical system that determine the rate at which the dissolved species become available for hydrological transport.

Thus the interaction of water, repository rock, and the waste material should control in such a way as to minmize the rate of dissolution of the waste form.

5.5.3 **Chemical and Physical Reaction of the Water with the Repository Rock**:

Interaction of water with the repository rock especially as the temperature rises, could alter containment of radionuclides by affecting the frequency and size of fractures, solution cavity, pore space and channels within the rock. The extent of such interactions would be affected by the mineralogy of the host rock, the amount and composition of the water and the nature of the transport within the rock,the initial size and spatial distribution of pores within the rock and thermal effects.

5.5.4 **Properties of the Geocheical System of the Radionuclide, the Reporsitory Rock and its Associated Water**:

Sorption of repository the dissolved ion by the minerals of the rock and be a significant factor in reducing the mobility of radionuclide. The rate and fraction of each produce carried to the bioshpere will thus be critically affected by the immediate geochemical mineralogical environment. This environment can be further managed by the addition of appropriate materials such as Zeolites, clays or other ion exchange basis of presently available date, it is evidance that minerals or resins. On the retention of the long lived α - emilters of neptunism, plutinism, americism and curimn can be sufficiently high incertain geochemical mineralogical environments to strengthen assurance of long term containment.

Thus the properties of the geochemical system of the radionuclides the repository rock and its associated water should be such as to restrict or prevent the mobility of the radionuclides and to delay or prevent their migration to the active bicsphere.

CHAPTER - VI

6. CHARACTERSTIC OF HOST ROCK FOR SAFER DISPOSAL

The waste isolation characteristics of different rock types vary greatly, according to their mineral composition, their mechanical & geological stability & their hydrogeological environment.

Host geological formations of potential interest include evaporites, other sedimentary deposits, igeneous & metamorphic rocks & in the case of shallow ground burial concepts, various soil materials.

However, the suitability of the host rock will depend on individual circumstances related to the specific site rather than the general properties of the host rock type. For example rock types which may be satisfactory under certain circumstances e.g. limestones and dolomites (Caleareous formations) do not prevent circulation of water. But dry mines are found in calcareous formations particularly where they lie between impermeable beds. [IAEA,1983].

Engineered barriers can serve the same purpose as naturally occurring impermeable beds. These barriers may be considered in the safety assessment and then become the part of the overall repository design as a means of mitigating the possible effects of a failure mode i.e.reducing the failure mode probability and/or its consequence severity.

Thus the fact that a final decision regarding the location of a radioactive waste repository can only be made after a very careful, accurate and comprehensive investigation of a given site and consideration of the waste characteristics.

The characteristics affecting the suitability of the following general rock types considered as host rocks for the disposal of radioactive waste that are described below.

6.1 **EVAPORITES:**

Evaporite, due to their low water content, high thermal conductivity and ability to act in a plastic manner which can make them self sealing has long been considered as a prime prospect for the disposal of high to low level of radioactive waste. [Roxburgh, 1987].

Evaporite, which occur in all the continents are mostly formed from minerals which precipitate under hot arid climate conditions in seas and large saline lakes. The resulting beds of evaporite minerals can be very thick and extensive [Roxburgh, 1987].

Evaporite deposit are extremely variable in both their mineralogy and their stratigraphy. The rocks of primary interest are halit, anhydrite and/or gypsum.

When the original volume of seawater is reduced by evaporation to about one half a little iron oxides and some $CaCo_3$ are precipitated. When the volume has been reduced one fifth gypsum is formed upon reduction to about one further to about the tenth of the original seawater volume, Nacl begins to crystallize Reduction of water below this leads to the appearance of sulphates and chlorides of magnesium and finally NaBr and Kcl [Roxburgh, 1987].

Additionally between the period of salt formation normal sedimentary processes may resume bringing in large amounts of clay and quantities of sand or extensive thickness of limestone may develop. The result is that it is not uncommon to find evaporites inter bedded with considerable thicknesses of shale Sandstone and limestone, all with marked by different hydrogeological physical and chemical property.

Gypsum can be altered to anhydrite when buried at depth, where the increase in both the temperature and pressure combine to drive off the two molecule of water in the gypsum. Massive an hydrite tends to impermeable and chemically stable. Availability of groundwater can however, reverse anhydrite to gypsum with an associated increase in volume which could potentially make anhydrite repositories self sealing if groundwater was able to enter. Against it the anhydrite has the tendency to be brittle and is prone to fracturing which may increase the chances of groundwater to pose problem in repository construction [Roxburgh, 1987].

6.1.1 **Positive Assessts**

Of which the rock salt (halite) has received the most attention. This most common of evaporities has been considered because of its favourable properties and its widespread occurrence as undisturbed units within geological settings, indicating long term stability [Roxburgh, 1987].

Rock salt exists as a bedded deposit formation or as large domes that are pushed upwards by diaprism. Salt is more plastic than almost any other rock and is thus able to seal fractures and repository excavations. This property makes salt largely impermeable to gases and liquids other favourable properties of the rock salt are good compressive strength good thermal conductivity and easy mineability.'

Because of the high solubility of salt in water, groundwater could breach the geological integrity of such a repository.

On the other hand, Anhydrite and Gypsum for formations are composed principally of calcium sulphate & its hydrate, respectively. They are soluble in water though less so than halite. They are relatively non-plastic & in some cases are prone to fracturing during mining operations. Their chemical compatibility with waste forms & other repository material may be superior to halite and their sorption characteristic for radionuclides are better.

Anhydrite is a strong rock, gypsum and potash are moderately strong while rock salt is moderately weak. The existence of salt diapire clearly demonstrate that salt when loaded can creep and will continue to do so until lithostate equilibrium is attained. Under tensile load the elastic limit of salt is very low but under pressure it behaves plastically Anhydrite and gypsum in comparison with halite undergo comparatively little plastic deformation. [Roxburgh, 1987].

6.1.2 **Nagative Assessts**:

Fluid Inclusions: The study of fluid inclusions and brines in halite and other evaporite minerals is considerably important. If these brines which are mostly composed of a mixture of potassium, sodium and magnesium salts are heated to between 250 and 280'C. they can explode violently.

Secondly, the heating of fluid inclusions in halite may also cause them to migrate up the temperature gradient by a processes of dissolution of salt on the hotter side, diffusion across the fluid and recrystallization on the cooler side. This will cause the undesirable effects in a High level waste repository firstly because it may concentrate hot potentially very corrosive brines around waste canister, secondly as the thermal conductivity of the brine is lower than that of salt local hot spots stress increases could develop around waste canisters and thirdly it could cause fluids in the surrounding rock to move towards the waste thus increasing the chances of fluid waste interaction. [Roxburgh, 1987].

6.1.3 **Hydrogeological Defects**:

Salt is quite soluble and evaporite deposits are potentially capable of dissolution on their margins where they come into contact with circulating ground waters.

The solution rate of evaporites is largely controlled by the surface area in contact with the water and the flow velocity associated with the unit area of the material. Evidence of dissolution at the top of salt domes is generally illustrated by the presence of a cap rock composed of a solid residue of less soluble materials left after the relatively much more soluble evaporite minerals have been dissolved out and transported away [Roxburgh, 1987].

If water gains entry to anhydrite beds subsequent hydration to gypsum can result in uplift. This comes about as a result of the 30-58% volume increase accompanying the hydration which can generate pressures as much as 60 MPa. The process of hydration may take place quite quickly and result in explosive release of pressure where the anhydrite beds are buried at depth [Roxburgh, 1987].

Water gaining access to habit deposits can result in rapid removal of salt material and the formation of cavities and surface subsidence.

6.1.4 Radiation Effect:

Radiation can result in a distordering of the crystal lattice in halite with a resultant storage of energy which can be released steadily as heat or explosives. It has been shown that this stored energy is mainly dependent on dosage and the temperature of the salt at the time of irradiation. As the temperature rises less energy is stored until by 150°C only a negligible amount is stored in salt. Thus the conclusion here seems to be that if the salt temperature can be maintained above 150^{o}C then energy storage problems associated with its irradiation can be avoided [Roxburgh, 1987].

6.2 ARGILLACEOUS ROCKS:

The argillaccons formation which includes clays, shales, mudstones, siltstone and marls are broadly by considered as the important host rock for high to low Radioactive waste as because it generally show very low permeability good sorptive character and low solubility and finally their ability to act in a plastic manner, which makes them self sealing in certain circumstances. The potential disadvantage includes dewatering of hydrons clay minerals in response to the thermal load, low thermal conductivity and adverse effects on rock mechanical properties presence of organic matter and gases existence of in homogeneities and possible difficulties in missing and keeping excavation open.

The argillaceous rocks mainly form from the deposition of clay particles and other detrital material in seas & lakes. They may also be derived from the in situ weathering of other rocks such as alteration of feldspar in granite to China clay and from terrestrially deposited material giving rise to rocks such as loss or the weathering of volcanic rocks to form bentonites [Roxburgh, 1987].

6.2.1 **Positive Assessts**:

In addition to this zeolite can play a significant part in reducing the mobility of radionuclides the argillaceous rocks of interest as High level waste repositories are for the most part formed of clay minerals.

It can be seen that the clays are made up of three different types of layered structures which combine in different ratio. For the 1:1 clays such as kaolinite for instance the repeating unit is one layer composed of one SIO4 sheet and one AlO_6 sheet. The water content ranging from as high as 22% by weight for the smectites to as low as 5% for the illite group.

The Kandite exhibit both the lowest Cation exchange capacity and the highest anion exchange capacity of the main clay groups. The highest cation exchange capacity is to be found in vermiculite [Roxburgh, 1987].

The presence of organic material in clay rocks is well documented owing to their believed significance in the production of hydrocarbons. These organic materials can have a significant impact even at concentration of 1% or less on the mobility of certain radionuclides. [Roxburgh, 1987].

Special mention needs to be made of bentonites which owing to its high cation exchange capacity has potentially important role to play as a backfill buffer medium within the multibarrer concept. It is composed almost entirely of montimorillorite and colloidal silca, produced as the alteration product of glassy volcanic debris.

6.2.2 **Heat Effect**:

From the above figure it is clear that the rise in temperature around a granite repository for example is unlikely to be as rapid as that around a comparable shale facility., Similarly as salt deposits generally conduct heat easiest of all the rock types under serious consideration, they would allow the most rapid transfer of heat away from repository. This makes it easier to keep rock & groundwater temperature as low as possible which it is generally agreed in highly desirable.

In clays as with the granite and evaporites, it has been shown that heat dissipation occurs overwhelmingly by conduction. It has been found that how the difference in thermal properties of clays potentially poses difficult problems for the designer of a High level waste repository. Younger clays which offer the desirable qualities of plasticity and low permeability often demonstrate poor thermal stability and pose difficult mining problems. On the other hand while a compact older slaty unit has better thermal stability and improved engineering properties it is also likely to have a much higher fracture permeability and thus a greater degree of groundwater access. The clay mineralogy and hence the radionuclide potential of a shale may also be altered by diagenetic processes with increasing depth of burial for example kaolinite and montomorillonite generally decrease in abundance with illite and chlorite related mineral. [Roxburgh, 1987].

Mineralogical changes would generally occur at about temperature 500 to 600^{o}C in the clay, Mineralogical changes in the clay seems to be limited to within 4m zone of the instruction while physical effects such as baking of the clay rock have been observed upto 12m from the heat source.

6.2.3. Hydrological Effect:

The porosity of freshly deposited clay sediments is very high reaching as much as 50% or more. However, in undergoing compaction and diagenesis this level of prorosity is markedly reduced. Hedberg has shown that the porosity of a shale under an overburden of 1800m or so would be only about 9%. [Roxburgh, 1987].

While porosity values of even 9% or so may still be considered high in the context of a HLW repository, however, owing to the very small size of the individual clay particles generally less than 0.003mm water contained within the pores is generally rendered immobile by retentive forces.

It is important at this point to repeat that argillaccons rocks can have very mixed natures and the presence of even small amounts of silt or sand grade material can markedly increase the potential for groundwater movement.

Heat generated by deposited waste will tend to drive groundwater away from the repository and this may move over considerable distances in well fractured clays and may result in the creation of convection cells.

6.2.4. **Clay Ability to Retard the Radionuclides Element:**

Clay has the relatively low values for thermal conductivity compared with the other rock types under consideration as HLW repositories, and this will limit initial design temperature for repositories in clay, probably to temperatures of 100^{o}C or less.

One of the important criteria of clay is having very high sorptive capacities while it is difficult to be precise about just how much of a particular radionuclide would be retained by a clay, the existence of this property in the rock surrounding a repository is very desirable. It has been found that sorption tends to decrease quite rapidly with rising temperature, a further reason to keep repository design temperature at or below 100^{o}C if possible. [Roxburgh, 1987].

The rate of sorption will also vary according to Eh, pH temperature and the mix of the radionuclide their relative solubilities and the presence of other material in solution. It has been found that the sorption of Sr is altered in the presence of Ca^{+2} despite the fact that strontium is better adsorbed than calcium on clay minerals.

The distribution coefficient is a direct measure of the retardation factor any chemical species will undergo when conveyed by an aqueous solution or when moving in a continuous water matrix.

The type of clay mineral involved will also be very important. As for instance the Boom clay contains vermiculite and Smectite clay minerals which make it an excellent sorbent for various radionuclides with an average cation exchange capacity of 0.30 + 0.05 meq g-1. [Roxburgh, 1987].

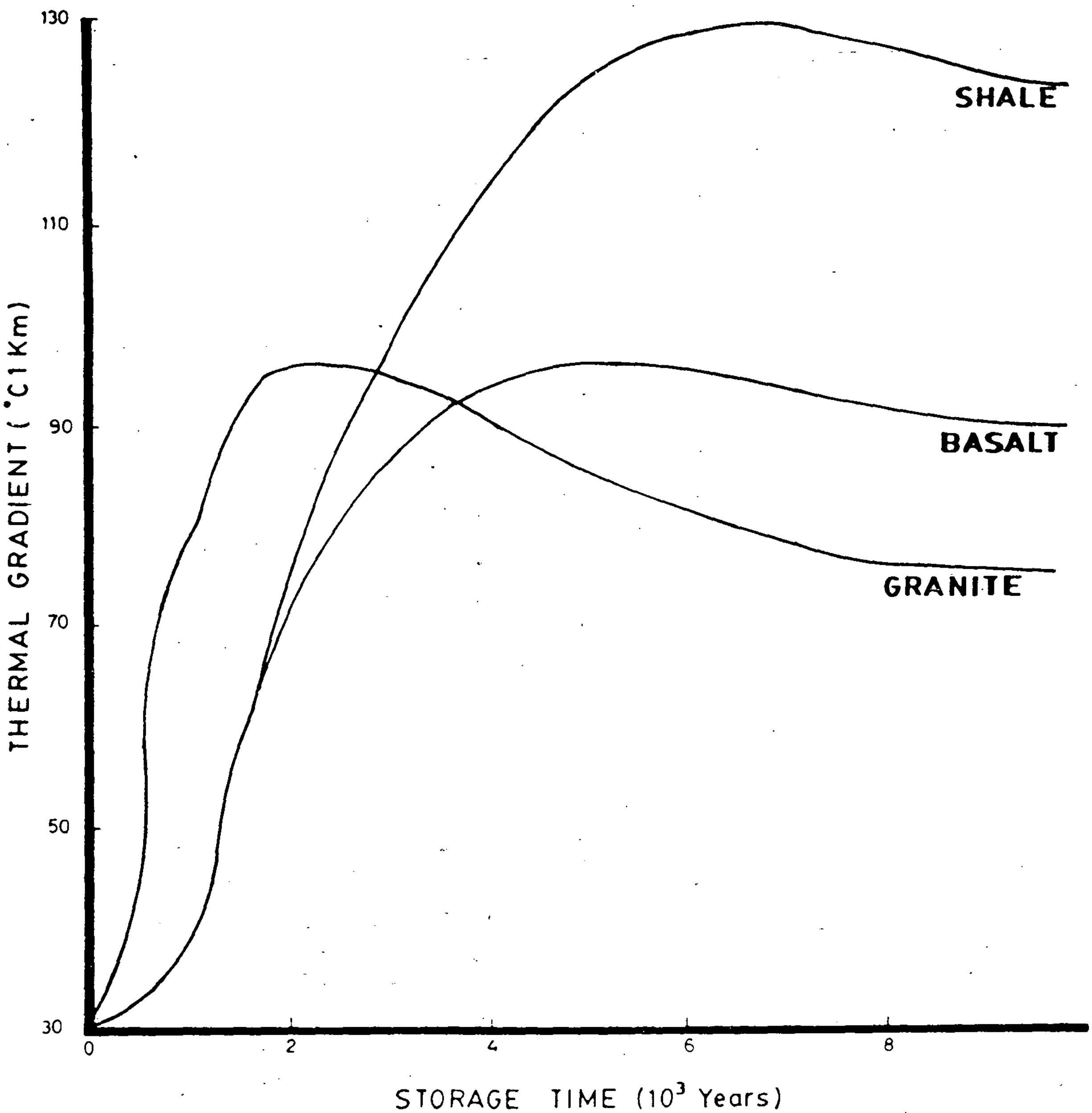
Again the presence of organic remains within the clay in the form of carbonaceous material may locally increase sorption but at the same time the presence of organometallic constituents which are often associated with carbonaceous shales may increase the transport of radionuclides through these clays.

Second most important property of clay minerals have relatively high ion and cation exchange capacities and in consequence show a potential to attract radionuclides to their surface, taking their from solutions contained within the rock [Roxburgh, 1987].

In general the reaction is quickest in minerals in which the exchange takes place along the crystal edges such as kalonite but where the adsorption process also requires the diffusion of the adsorbate into the adsorbent as in montmorillonite the exchange is much slower. In illite where the basal planes are firmly bonded together the whole process of con exchange is even slower.

6.3 CRYSTALLINE ROCKS:

Crystalline rocks are considered by several countries as prime candidates for the repository for



THERMAL GRADIENT RISE AT GROUND SURFACE ABOVE CENTRE OF REPOSITORY IN DIFFERENT ROCK FORMATIONS

AFTER ROXBURGH - 1987

Fig.6.1

underground disposal of radioactive waste. They generally demonstrate long term stability, moderately good thermal conductivity low porosity, high rock strength, good chemical stability, resistance to weathering, relative dryness, ability to retain radinuclides within the rock mass and their high melting point. [IAEA, 1983].

While the range of crystalline rocks are under investigation such as gabbso, hasalt, tuffs but it is principally the granite which seems to be best suited to high level as low level waste disposal.

6.3.1 Positive Assessts with Respect to Granite:

The minimum melting point of a granite at 1 bar is about 960°C, but at a depth of 3km this will have fallen to about 250°C. However, the presence of fluids within the Granite will markedly alter its melting point. It means that the majority of Granites high in erosional sequence are likely to have been dry magmas which has been shown by the lack of hydrous minerals but in contrast the granite from deeply eroded area are likely to contain a high proportion of hydrous phases. Thus the observation of this fact is that at relatively high temperature certain hydrous minerals in granite may altered in such a way as to release their volatiles. Thus for deciding a suitable repository design temperature it is unlikely to be significant at temperatures below 250^{o}C. [Roxburgh, 1987].

Fractures and joints in granites are common though at depth these tend to be tightly closed. Fractures and joints are often concentrated in narrow zones.

Major fissures in crystalline rock may in turn be connected to an extensive network of microfissure. These microfissures are important as they provide a means by which radionuclides escaping from a repository diffuse into the rock matrix where they may be effectively immobilized over quite short distance. Thus the diffusion of radionuclides into granite microfissues would result into the decay of the important chains such as 241 Am, 237 Np, 220Th & 226 Ra to insignificant levels. [Roxburgh, 1987].

Fractures and joints in granite may result from the cooling and associated contraction during their emplacement in the earth crust. Although as the most of the granite were formed between 250 million and 2000 million years ago they will have cooled to the appropriate temperature for their depth of burial and further joint formation associated with cooling is unlikely yet it is important to note that heat generated by the waste and subsequent cooling may alter the size and extent of existing fissures. Thus it is more important that fracture zones are correctly detected and avoided in repository location. [Roxburgh, 1987].

6.3.2. Hydrogeological Effects:

Most granites would be intimately associated with sedimentary formations which can often form good aquifers. While underlying acquifers would not normally be expected in association with granites though these could theoretically occur where granite takes on a sheet like mushroom form in their upper region, they may readily be overlain by aquifers rock formations. Under such circumstances it is important to establish an interconnection between the overlying aquifers and the granite groundwater and/or the HLW repositories is to be located sufficiently distant from marginal acquifers. [Roxburgh, 1987].

6.3.3 Radiation Effect:

The physical properties of crystal structures can be altered by radiation of high energy particles both by the physical alteration of the crystal lattice and by the production of free electrons and other changes. The physical properties of the minerals within a granite may be significantly altered by such radiation effects resulting in changes to density, hardness, unit cell volume and brittleness. While heating can bring about annealing and repair of radiation damage because of the volume change which may be involved, minerals in the immediate vicinity of a repository may be shattered with consequent alterations to the hydrogeological properties of the rock.

6.3.4. Positive Assesssts with Respect to Basalt:

Basalts are normally formed in sheets or flows, though they can occur as vertical dykes or in other interusive forms. The flow may range from a few metres to over 100m in thickness, with individual flows having markedly different mineralogies and physical characteristics.

Basalts may be able to retard significantly the passage of radionuclides, through sorption or to contained zeolities and montmorillonite clays derived from in situ chemical changes on the surface of rock fractures. Basalt are hydrogeologically very complex largely as a consequence of their varied physical characteristics and layered nature, Dense flow interior basalts tend to have very low values for porosity and hydraulic conductivity. [Roxburgh, 1987].

The vertical joints common in basalt allow water to move vertically through lava piles providing unconfined conditions in places.

6.3.5. Positive Aspects with Respect to Tuffaceous Rock:

Tuff is primarily indurated volcaniclastic ejecta deposited either directly or reworked and redeposited by other surface processes.

Vitric tuff-which are characterized by an abundance of glassy materials and shattered pumices.

Crystal tuff-formed of mineral crystals the minerlogy being determined by the nature of the original magma and

Lithic tuffs-which are marked by a dominance of volcanic rock fragments. This matrix material in most tuffs tends to be predominantly glass ash.

Welded tuffs-are a special group deposited at very high temperatures, generally above 500°C, which welded the various ash component together.

The Poroity and hydraulic conductivity of a tuff varies according to whether it is welded or not. Porosity values for welded tuff are of the order or not. As it has been suggested that the porosity of tuff is inversely proportional to the degree of welding. Tuffs also have a well developed ability to retain large quantities of water within their available pove space even when it is situated above the water table.

CHAPTER - VII

7. CHARACTERISTICS OF SEABED FOR THE DISPOSAL OF HIGH LEVEL RADIOACTIVE WASTE

Waste produced from the nuclear fuel cycle as well as from the existing activities such as civil and military must be disposed of in the suitable condition. Recently attention has been focused on the possible future use of deep sea sediments as a repository for the disposal of both high-level and medium-level radioactive waste. A positive feature of this disposal option is that the deep-ocean sediments would act as a geochemical barrier to the release of long lived radionuclides to sea water and the marine food chain and thus to man.

The concept envisages the waste would be verified and then packed into container and over packed before being placed on the seabed or buried at varying depths within its soft sediments covering and the underlying lithified sediments or oceanic hasalt. An appreciation of the sealed concept requires a knowledge of the nature of the sealed and its sediments the development of the appropriate emplacement technologies and an understanding of how escaping radionuclides will be transported and how they could effect the life of ocean.

The inland seas, continental margins and shelves are clearly unsuitable, being generally quite shallow and with important fisheries oil and other mineral interest. It may also be considered that by definition such seas are unnecessarily closed to the land masses and man's habitation. Similarly the seismically active mid-oceanic ridges would not be suitable for disposal.

The search for seacbed disposal sites is therefore confined mainly to the region between these two areas, thus the area of ocean basin floor composed of deep oceanic trenches and the surrounding ahyssal hill plains are two of most interest. In general the researcher concentrated on the ahysssal plains owing to their greater thickness of sediment, their relatively low economic importance, low biological activity and their seismic passivity. [Roxburgh, 1987].

Following are the various factor for determining the suitable area for the disposal of Radioactive waste:

A. Two main criteria for selection of seabed disposal are-

i) Stability and

ii) Barrier

7.1 STABILITY FACTORS

7.1.1 Site Area:

The site selection will largely depends on he disposal method,the spacing between penetrators and the number of waste canisters per penetrator. Generally the horizontal spacing between two waste camisters of about 250m is envisaged.

7.1.2. Area Bathymetry:

Here the main emphasis is given to the sites that are free from turbidity current and sediment slumping i.e.,. the slopes should be very gentle idealy no move than 1:1000 i.e. the area should be distant from step canyons and slopes

7.1.3. Thickness and Structure:

For the shallow penetrator the thickness should be at least 30m and accepting that a comparable thickness of sediment should exists below the conister as well as above them a minimum thickness of about 60 m would be required. For drilling purposes the economic factor should also be taken into account, but its unlikely that each sediment thickness should not be less than 400m. [Roxburgh, 1987].

7.1.4. **Stratigrphy**:

Many sediments show marked variation both vertically and horizontally, whereas ideal repository site will show a high degree of uniformity and continuity in terms of its stratigraphy. Although the disposals is possible in the site where the continuous accumulation of sediment for a period of time which is equivalent to the length of time during which the release of radionuclide may be a hazard to man.

7.1.5. **Physical properties**:

If the waste burial would occur by the self penetrating the sediment should be visco elastic & plastic to a considerable degree. Thus the presence of significant boulder or gravel layers will make the effective self sealing of holes less likely as well as potentially reducing the depth and accuracy of penetrator emplacement. [Roxburgh, 1987].

7.2 BARRIER FACTORS

7.2.1 **Sorption clays**:

It is be expected that the fine clay particles within the unconsolidated seabed sediments will be able to reduce the rate of migration of escaping radionuclides by the process of sorption. Thus it would be advantage of site with a predominance of clay as opposed to sand or other material with lower sorption capacity. [Roxburgh, 1987].

In deep ocean carbonate zones, the carbonate matrix is slowly dissolving resulting in a net release of ions and thus the lower adsorption capacity for the solid phase. The increased carbondioxide at the depth due to the coolness of water result in an increase in the rate of dissolution of the carbonate material at depth. Hydrostatic pressure would also cause the increase in the rate of dissolution of the carbonate material at depth Hydrostatic pressure would also cause the increase in the concentration of CO_2 content.

7.2.2. **Porosity**:

The radioactive material may be transported by mobile pore water. Pore water may be mobilized by compaction of unconsolidatd sediment or by the release of thermal energy from the contained waste. The rate of pore water advection at any particular site should be less than the rate of transport by other mechanisms such as diffusion. The chemistry of the pore water will also be important. The solubility of some ions is increased under ion oxidation conditon while other show similar increased solubility under high oxidation levels. [Roxburgh, 1987].

7.2.3. **Bioturbation**:

Animals are unlikely to burrow from the surface to the likely depths of canister burial successive burrowing at previous sealed sediments level has to be taken into account. The presence of burrow in excess of 1% of the total sediment volume to the depth of burial should be considered as undesirable characteristic.

7.2.4. **Depth of sea**:

In general it is most likely that sites with a cover of at least 400m of seawater will be chosen. [Roxburgh, 1987].

7.3 DUMPING THE WASTE FORM AND THE CANISTER:

The term dumping has been defined as any deliberate disposal of Radioactive waste into the sea or other matter from vessels, aircraft, platforms or other man made structure at the sea.

The waste is generally packed into steel drum, often in a concrete matrix, and simply dropped over the side of the dumping vessel. The main function of the steel drum is to ensure that the container reaches the ocean floor intact as well as making the waste easier to handle. [Roxburgh, 1987].

The dumping of these relatively low level, non-heat generating wastes should not be confused with dumping of high level nuclear waste which is considered unsuitable for dumping in a similar manner.

Like land based waste disposal, the waste which is disposed in the ocean should be incorporated into a borosilicate glass. The susceptibility of these glasses suggest that there is no marked differences between the leach rates for seawater and ground water.

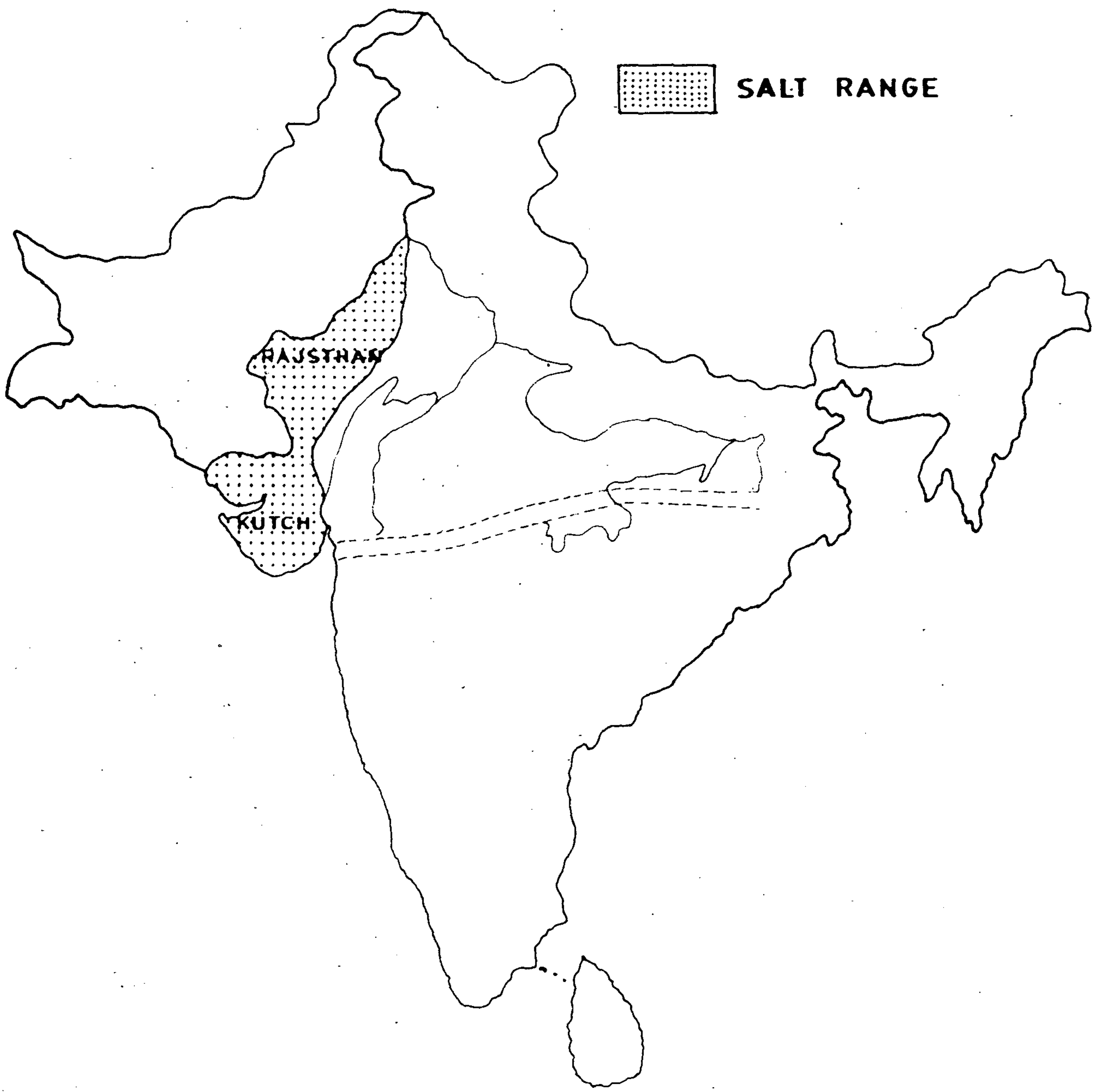
In case of sea had disposal the projected time period for containment can vary. Thus under certain situation it should be rely on the nature of waste form, the surrounding sediment and seawater cover to provide the necessary degree of isolation. [Roxburgh, 1987].

Generally two canister concepts are under invetigation to provide for the longer periods of containment required. The first is titarium based alloy while the second is made up of mild steel. The first is although thin but highly erosion resistance. While the second work on the sacrificial basis, Utilising a thick overpack. [Roxburgh, 1987].

A container thickness of about 75 mm would generally suitable for the erosion caused by Γ-radiation as well as other emitting radioactive rays. other container which is generally made up is carbon steel and soft iron made.

The hydrostatic resistance requirement can be met either by the use of rigid container or by the use of the one which would transfer the load in part to the container contents.

CONSIDERED HOST ROCK IN SALT RANGE



TECTONIC MAP OF INDIA

AFTER KUMAR - 1982

Fig.8.1

CHAPTER - VIII

8. DESCRIPTION OF THE SUITABLE INDIAN HOST ROCKS FOR THE PROBABLE SITE SELECTION OF RADIOACTIVE WASTE DISPOSAL

Taking the geological condition of India and the requirements described in earlier chapter, following are the various types of geological formations which might be considered as suitable host rocks site for the disposal of Radioactive waste ranging from the low to high grade of Radioactive waste.

i). Host Rock region in the salt Range of Cambrian age

ii). Host Rock region in the Aravalli system

iii). Host rock region in the Vindhyan formation

iv). Host Rock region in the Dharwarian formation

v). Host Rock region in the Deccan trap

These region are located in the following geological and the hydrogeological map of india.

8.1 SALT RANGE OF CAMBRIAN AGE:

The salt Range of the Potwar plateau is considered to be one of the important region for the Radioactive waste disposal.

The salt range constitutes the southern edge of the Potwar Plateau between East longitudes 71° and 74°. The salt range forms a series of irregular ridges which are convex towards the south. The region attain an average height of 750m to 900m. [Krishnan, 1982].

The arcuate form of the salt Range is considered to the formed by the movement which compressed the strata and made them flow over some distance towards south the eastern & western end having been held back by wedges of ancient rocks which we underneath & which may be called the platean Kashmir and Mianwali wedge.

There are four stratigraphic break in the succession of in the salt Range-

i) the first between the Cambrian and the Talchir horizon

ii) the second below the Upper Jurassic

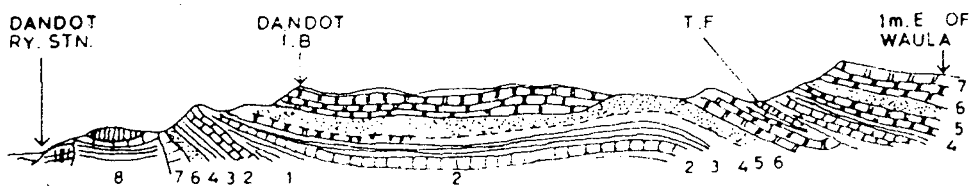
iii) the third below the Eocene and

iv) the fourth below the Muree

Following are the cambrian succession of the salt Range.

Salt pseudo-morph shales (upto 105m)	Red to purple and greenish sity shales with casts pseudomorph of salt crystals showing on bedding planes contain some gypsum.

CAMBRIAN SUCCESSION OF SALT RANGE



8) LOWER SIWALIK
7) NUMMULITIC LIMESTUNE
6) SPECKLED SANDSTONE
5) SALT PSEUDOMORPH
4) MAGWESIAN SANDSTONE
3) NEOBOLUS SHALES
2) PURPLE SANDSTONE
1) SALT MARL

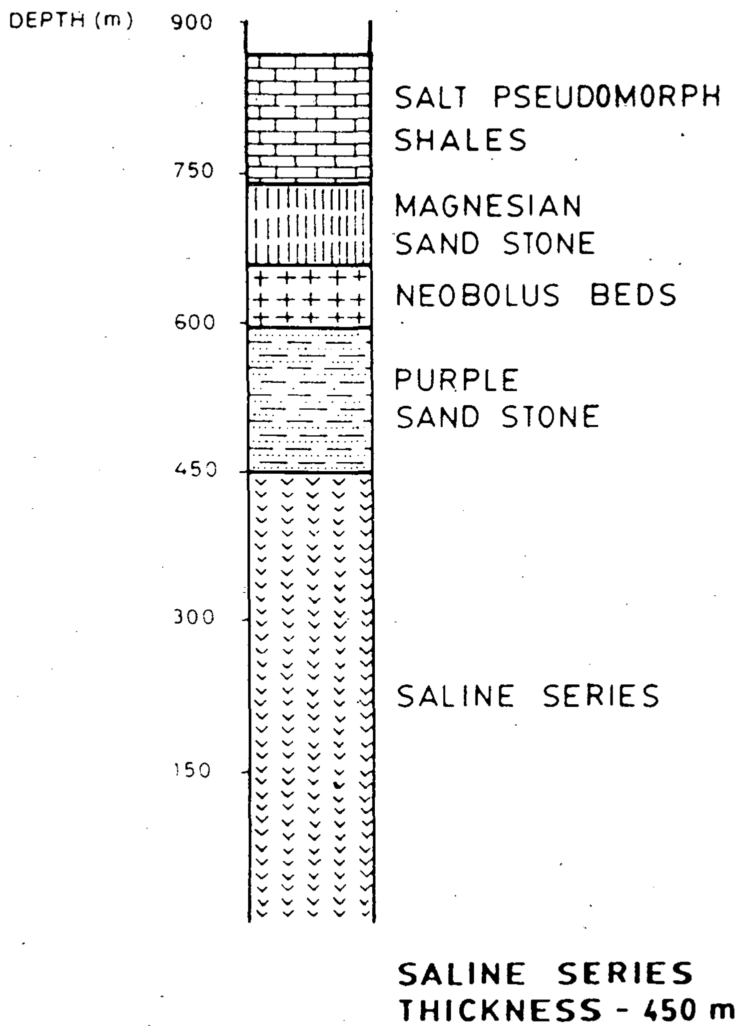
AFTER KRISHNAN - 1982

Fig.8.2

Magnesium sandstone upto 75 m	Well bedded cream colored dolomite sandstones sandy dolomite and subordnate shales.
Neobolus Beds (upto 45m)	Fossibiferous grey shale sandy shales sandstions which may be micaceous dolomitic and glanconitic pebble bed had at the base characterized by Neobolus and other brachiopods as well as some trilobites.
Purple sandstone	Fine grained pink purple and maroon (75-140m) sandstone. Lower part shals and flagstone
	c) Upper Gypsum dolomite with oil shale Saline Series decomposed diabase khwara trap
(salt Marls upto 450m)	b) Pink, red or purple salt mart with beds of rocksalt.
	a) Lower gypsum dolomite with oil shals

The Saline Series or the salt marls are considered to be the most suitable formation at the depth of 450m from the surface for the disposal of Radioactive waste.

The salt Range consist of three stages



CAMBRIAN THICKNESS OF SALT RANGE

AFTER KRISHNAN - 1982

Fig. 8.3

a) a lower gypsum dolomite stage containing beds of gypsum anhydride, dolomite, variegated gypeons clays and oil shalls

b) salt most stage consisting of red marl with thick seams of rocksalt and an

c) An upper gypsum dolomite stage consisting of massive white or grey gypsum and delomite with oil shale

A lower stage consists mainly of rock salt with at least six seams of salt having a thickness of 230m or more while the upper stage contains gypsum, dolomite, impure limestone, green shales and oil shales having a thickness of about 30 m.

The marl forms a practically an unstratified mass conspicuously red to dull purple or maroon in colour and contains grains of sodium chloride gypsum and carbonates of calcium and magnesium. Indication of stratification in the marl are given by the presence of layers of salt gypsum or dolomite.

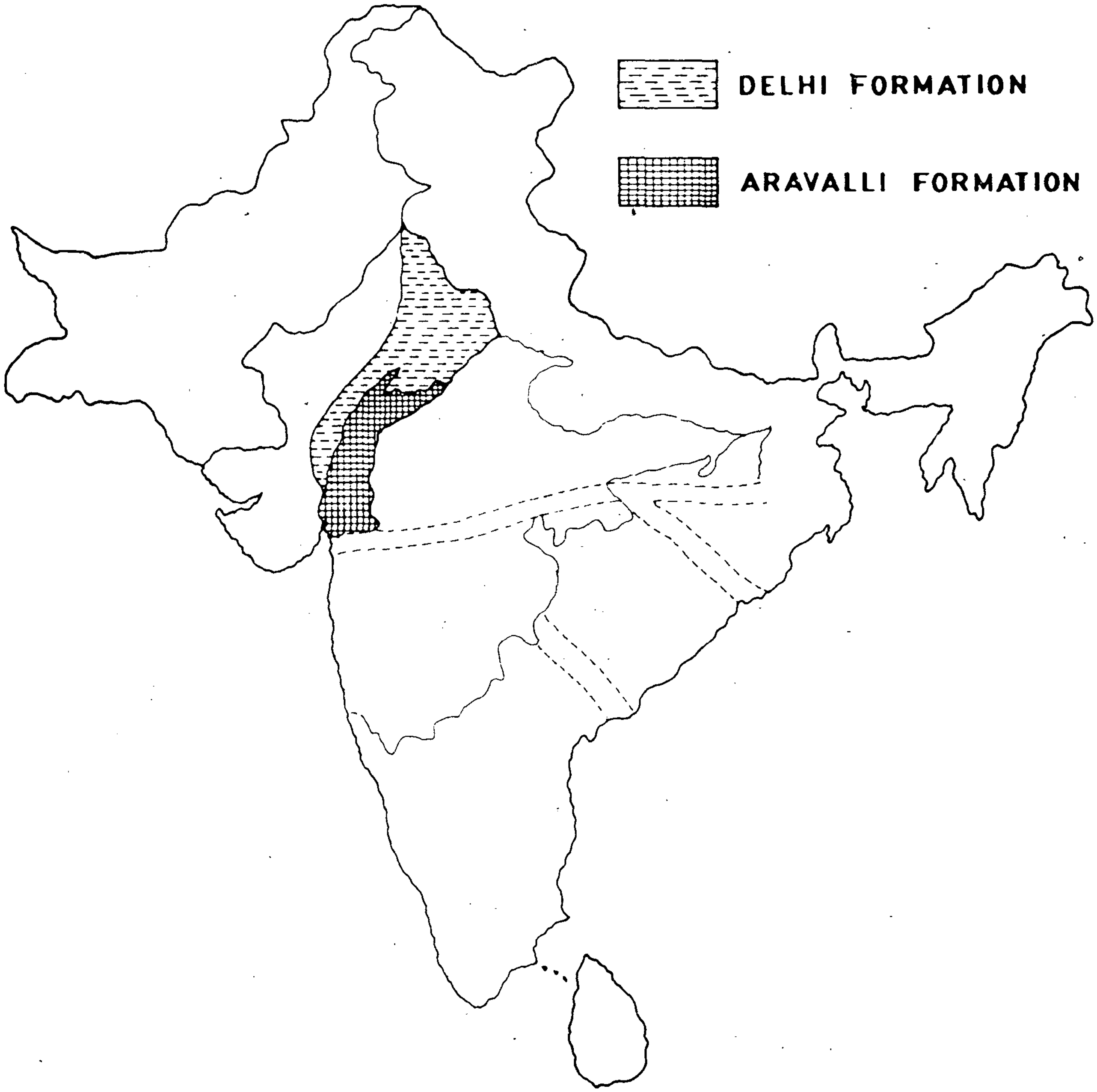
There are also unastomising and filmy stringers of gypsum in the marl indicating the tendency of the gypsum to segregate. The dolomite in the marl form honey combed lumps and it has been pointed out that there is complete gradation between the lumps and the streaky patches. The inference is that these patches are the result of disintegration of the layers of dolomites and their assimilation by the marl. The dolomites first becomes dotted with punctures which gradually become enlarged to produce a honey combed or spongy structure, the holes being filled with gypsum. [Krishnan, 1982].

The saline series is best developed at Khewra in Eastern salt Range where the lower portion shows beds of pure rock salt which is colourless to pale pink. The gypsum in this series is generally pure but sometime also show a gradation to limestone and dolomite. It is compact and massive to saccharoidal, white, grey, dark bluish grey or pink and sometimes even variegated plates of salenite are occasionally found while in some cases the enterior of the mass may consists of anhydrite. The beds and lenses gypsum contain excellent small doubly terminated crystals of quartz. These crystals some time contain inclusion of any anhydrite.

Another important evaporite coustituent i.e., the rock salt is also found to be associated with this series. The beds of rock salt are here massive and may sometime he as much as 30 m thick. Minute folds may be seen in the salt particularly in the associated layers of salt marl. The kohat salt shows the presence of calcium sulphate but not of potash or magnesium salt. The Khewra and Nupur in the Eastern salt Range contain less magnesium and more potash. The more common ingredients in the salt are sylvite (KCL) kieserte (Mg So_4 H_2O) langbeinite $[(k_2 Mg_2 SO_4)_3]$. In the Mayo mines at Khewra there are four to five beds of salt with an aggregate thickness of over 60m.

As it is well known that the evaporite is potentially capable of dissolution when they either come in contact with either the circulating water or the ground water. From the above mentioned hydrological conditions from the other available date the region is particularly devoid of both circulating as well as the ground water contact as because the annual rain fall in this region is considerably low second major defects which may effect the storge pattern is the Radiation released due to the resultant storage of energy. Upto temperature 150^{o}C only a negligible amount of energy is stored in the salt, thus the temperature should be maintained nearly about this temperature. Another considerably important material which would cause effects on the disposal pattern is fluid inclusion and brine composed of mixture of potassium, sodium and magnesium salt when heated to the temperature of about 250; & 280^{o}C explode violently.

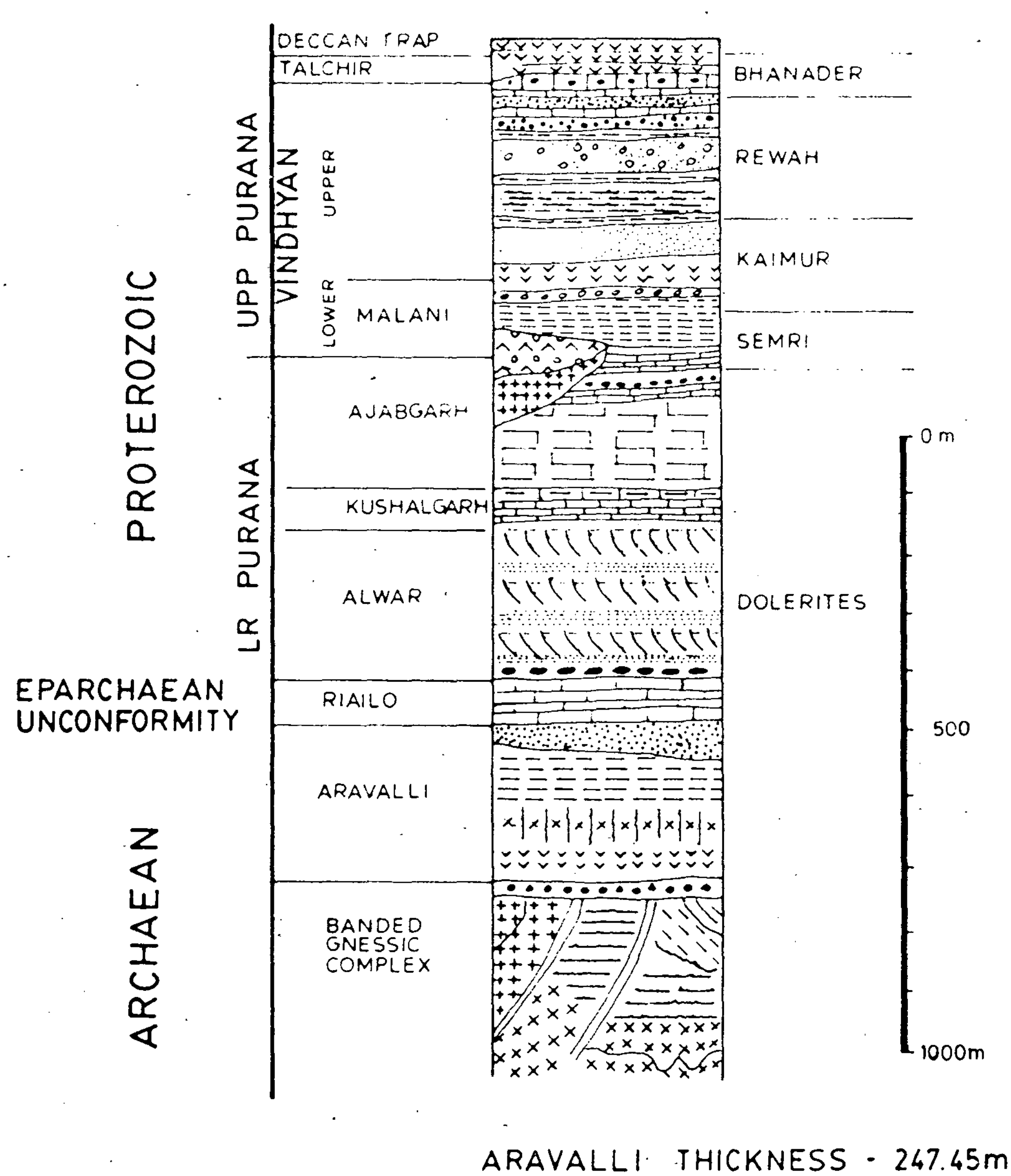
CONSIDERED HOST ROCK IN ARAVALLIS



TECTONIC MAP OF INDIA

AFTER KUMAR - 1982

Fig. 8.4



STRATIGRAPHIC OF THE ARAVALLI ROCKS

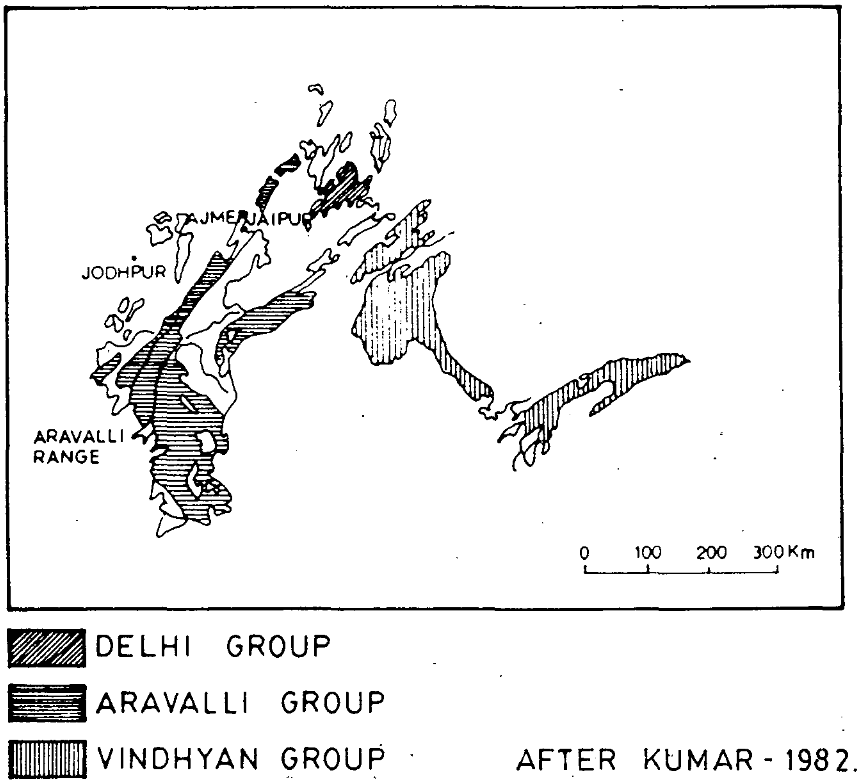
BASED ON GANSSER 1964

Fig.8.5

8.2 HOST ROCK OF ARAVALLI SYSTEM

```
Pre-cambrian              Delhi System
----------- Unconformity--------------
                  |     Raialo series
                  |------Unconformity-------
                  |    Aravalli system
Archaean  <------ |
                  |------Unconformity-------
                  | Banded Gneissic complex &
                  | Bundelkhand gneiss
```

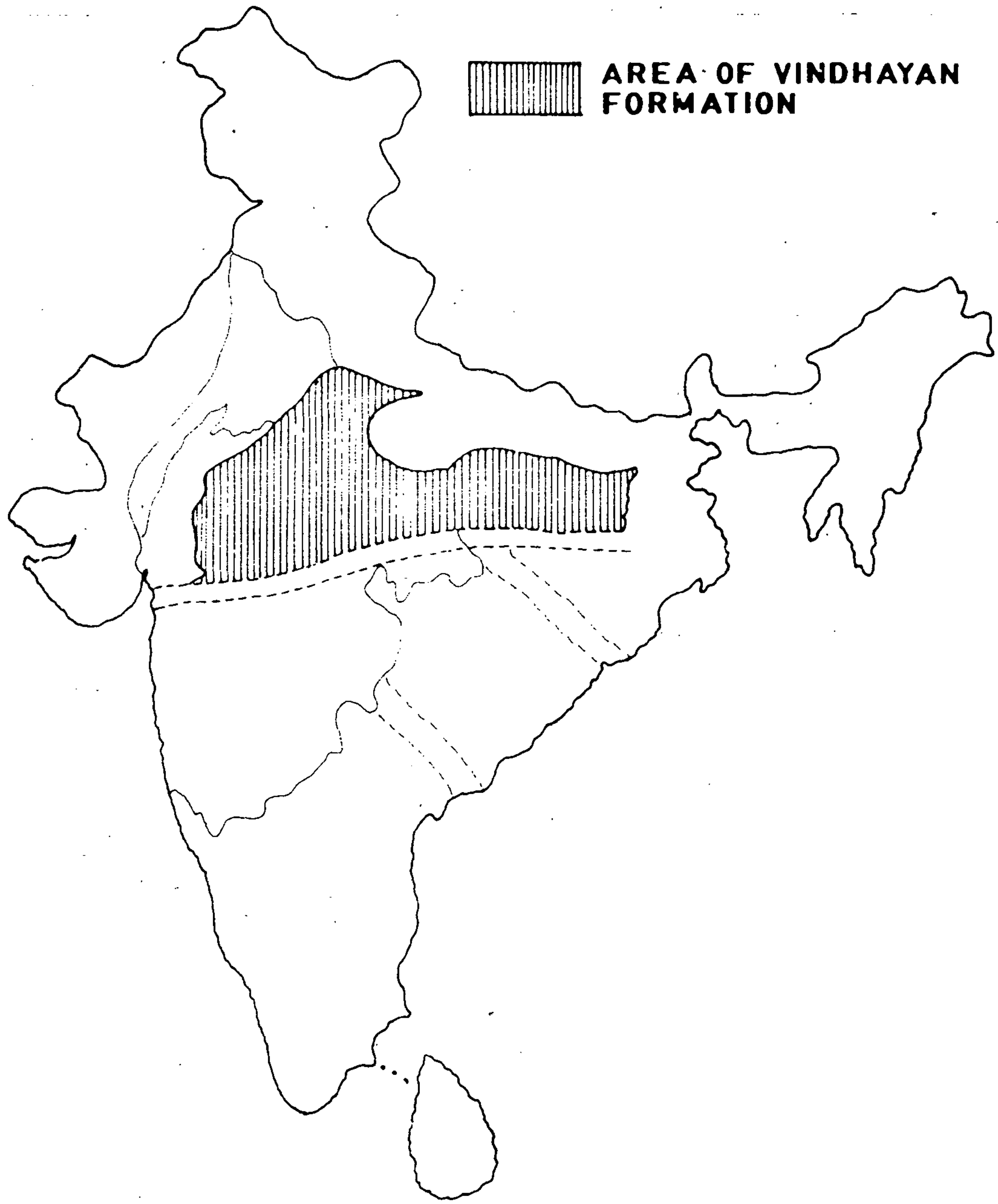
The rocks belonging to the Aravalli system are made up of argillaceous materials and constitute a very thick column of sediments. The bottom most beds of this system are quartizites, grits etc. Which are overlain by shales phyllites the associated volcanic rocks of basic composition. These argillaceous rocks shows prograde metamorphism towards the core of the Aravalli Range grading from almost unaltered shales in the east through phyllites in the centre to high grade schists in the west. The bottom most rock in followed upward by the ferruginous and argillaceous limestones and at place by quartzites, Reddish quartzites and sandstones known as Ranthambhor quartzite form the uppermost part of the Arravalli system. As a result of metamorphism the Aravalli rocks of the main synclinorium are distinctly foliated and have given rise to



DISTRIBUTION OF ARAVALLI, DELHI & VINDHYAN ROCKS

Fig.8.6

CONSIDERED HOST ROCK IN VINDHYANS



TECTONIC MAP OF INDIA

AFTER KUMAR - 1982.

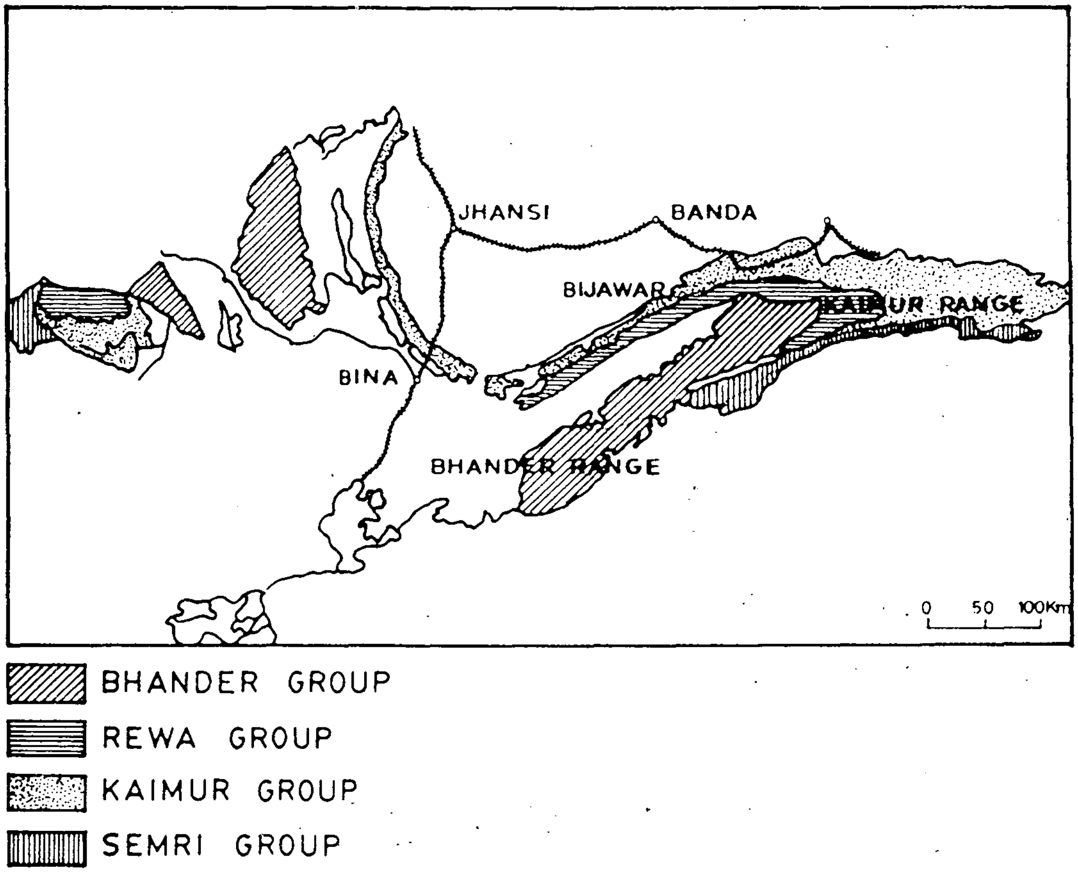
Fig.8.7

mica-schists. Granitic injections, in the Aravalli sequence have led to the development of composite gneisses on the eastern side of the great boundry fault the Arravalli rocks are unmetamorphosed and are known as the Binota shales. This argillaceous formation are olive to brown variegated shales with purple sandy, micaceous and often ferriginous beds. [Mukerjee, 1980].

Owing to the very variable nature of their mode of formation and the non uniform combinations of minerals likely to be found in the argillaceous rock, they cannot be treated as the spatially homogeneous isochemical systems obeying basic petrological principles. Secondly even on a small scale highly heterogeneous deposits can be encountered with the argillaceous rocks merging into certain of the other sedimentary rocks as in this case would be shale and sandstone and finally the principle shale minerals can undergo quite complex transformation as a result of metamorphism. But the region is thick and covered by thick slates and phyllite. So it would be considerable site for a radioactive disposal as excavation in this belt would be easy and would practically devoid of hydrogeological as well as underground water.

8.3 HOST ROCKS OF VINDHAYAN FORMATION

Considering the hydrogeological condition as well



GEOLOGICAL MAP OF VINDHYAN ROCKS

BASED ON AUDEN 1933

Fig.8.8

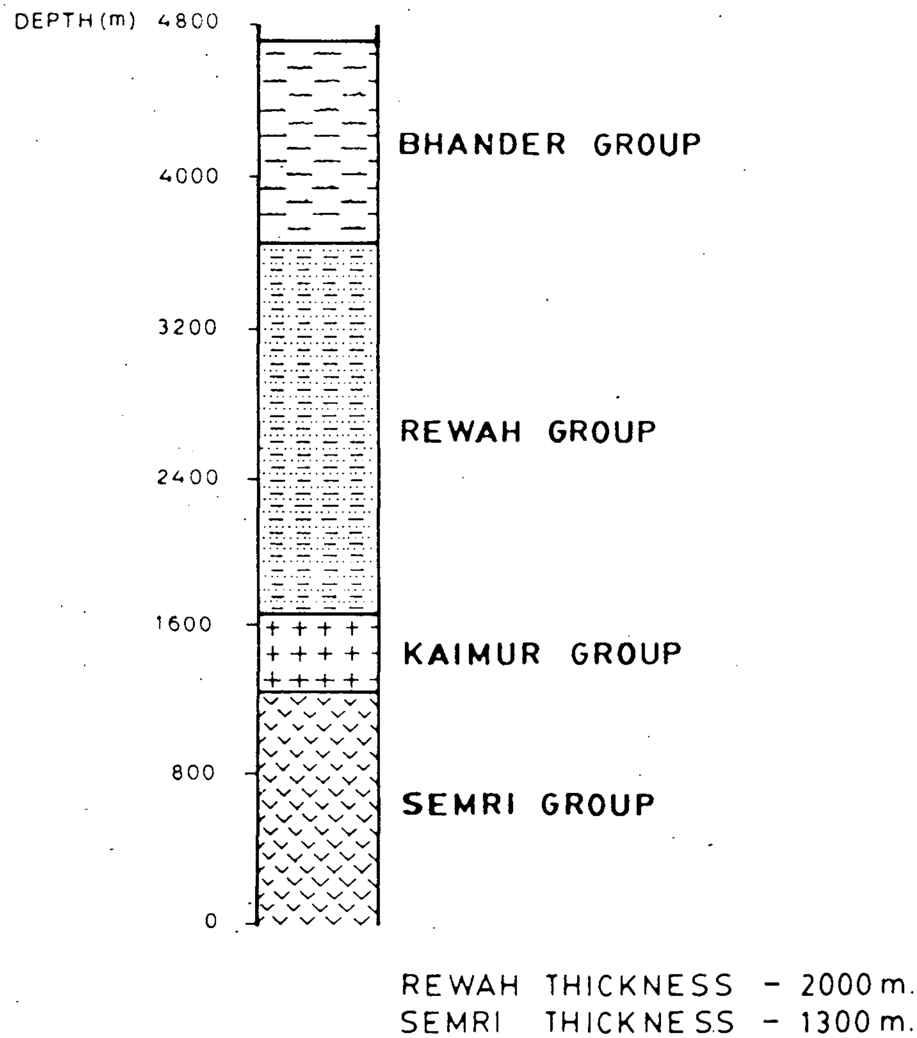
as taking the economic value of this formation the calcareous Siliceous rocks of the vindhayan formation might be considered as the suitable sight for the radioactive waste disposal.

The lowermost beds of this system in the sone valley are about 600m thick and consist of basal conglomerate and limestones beds. They are followed by shales sandstons have been silicified and converted to porcellnite attaining a thickness of about 100m. Overlying Kheinjua stage of about 180m thick consists of shales limestomes and glauconitic sandstones. [Kumar, 1982].

The limestone varies in quality from bed to bed much of being high grade containing over 80% calcium carbonate less than 3% magnesium carbonate and about 10% silica.

The upper vindhayan which are exposed in the vindhayan basin, consist largely sandstones shales with subordinate limestones and the sandstone forming extensive plateaux around.

In the great vindhayan basin the sandstone and quartzites form a series of well worked scarps while the intervening strata being soft. They persist overlarge area with fairly uniform characters. Taken as the whole the sandstone form plateaux while the shales limestones show



STRATIGRAPHIC THICKNESS OF VINDHYAN

AFTER KUMAR - 1982

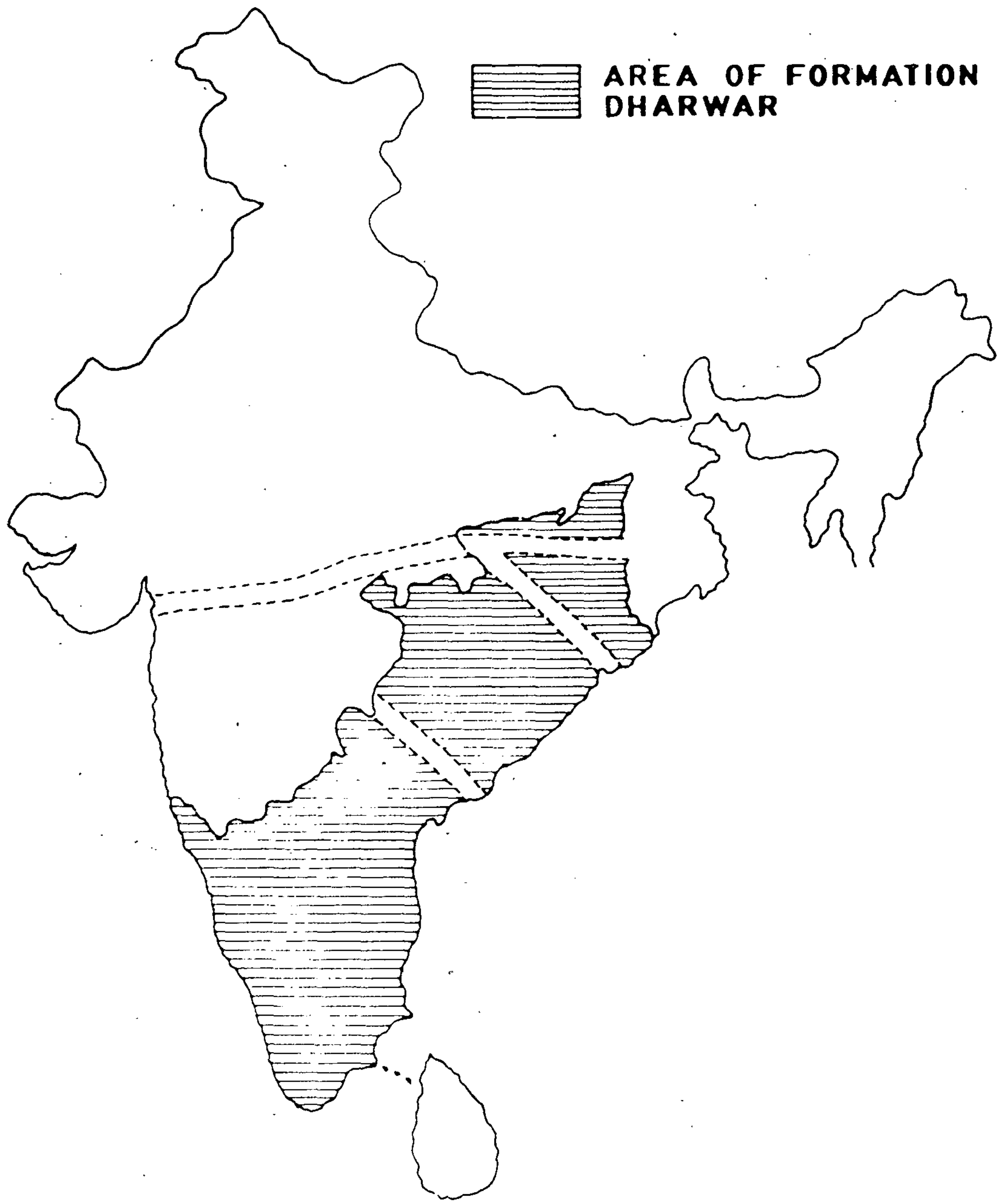
Fig.8.9

interbedding character. The vindhayan are thickest in the southern and south western areas. The margin of the vindhayan basin show a good development of sandstones while the shales are best developed in the centre which passes gradually into sandstone. [Krishnan, 1982].

Following are the thickness and classification of the vindhyan formation. [Kumar, 1982].

		Upper Bhandar Sandstone	1000m
		Sirbu Shale	
	Bhander Group	Lower Bhander Sandstone	
		Bhander Limestone	
		Ganurgarh Shales	
	-------Diamond Bearing Conglomerate---------------		
UPPER VINDHYAN	Rewah Group	Upper Kaimur Sandstone	2000m
		Jhiri Shales	
		Lower Rewah Sandstone	
		Panna Shales	
	--------Diamond Bearing Conglomerate--------------		
		Upper Kaimur Sandstone	400m
	Kaimur Group	Bijagarh Shales	
		Lower Kaimur Sandstone	
------------------Unconformity---------------------------			
		Suket Shale	1300m
		Nimabahara Limestone & Shale	
		Conglomerate & Sandstone	
		Khenjua formation	
		Gluconitic Sandstone	
		Fawn Limestone	
		Olive Shale	
LOWER VINDHAYAN	Semri Group	Porecllenite formation	
		Porcellinic Shale	
		Trappoid Beds (Sandstone Greywacke)	
		Porecllinic Shale	
		Basal formation	
		Kajrahat Limestone	
		Bleaching Shales	
		Basal Quartizites and Conglomerates	

CONSIDERED HOST ROCK IN DHARWARIANS



TECTONIC MAP OF INDIA

AFTER KUMAR - 1982

Fig.8.10

The calcareous formation in this region are moderately soluble and mostly dry. The pathways of the circulating water which generally cause dissolution of these rocks can be effectively checked by applying the engineering barrier which is supported by the natural barrier. Generally the Paleozoic limestones are quite impermeable as it would be considered in this case.

On the other hand the argillaceous formation which are generally interbedded in the form of rhythmic pattern are porous and permeable which is checked by the engineering barrier. Depending on the type of radioactive waste it lower vindhayan which economoically less valuable would be suitable region for the host rock.

8.4 DHARWARIAN FORMATION AS THE HOST ROCK

Depending upon the hydrogeological conditions, geological stability, the uniform thickness and the economic suitability of the region the rock of the Dharwarian super group and particularly the clospet granite is considered to be the best suited rock for the disposal of radioactive waste.

Dharwar super group is the thick sedimentary volcanic deposition mainly basic to ultrabasic rock. The Deposition in this region is relatively continuous geological history. Sediments of Dharwar supergroup were laid in elongate proto- geosynclines over a basement of sargur schist and Peninsula gneissic complex. The older schists showing high grade metamorphism mainly of grunulitic facies is known as sargur Schist complex (Older Green Stone belt) were later intruded by the Peninsular Gneissic complex and together they form the basement for the deposition of Dharwarian supergroup. The youngest element of the precambrian basement of the Dharwar region are the plutonic granitic rocks known as closepet granite.

Sargur schist complex are largely composed of metamorphosed products of ultra mafic, products of ultra mafic rocks, quartzites, carbonates and argillaceous sediments. This rocks have undergone high degree of metamorphism ranging from amphibolite, to lower granulite facies. Peninsular Gneissic Complex are typically migmatitic gneisses alternating with hands of amphibolites and tonalites. Variation shown by the peninsular gneiss are attributed to intimate mixing and interaction of tonalitic magma with the pre- existing mafic and ultramafic rocks and associated sediments of the sargur schist complex. [Kumar, 1982].

The much younger than the peninsular gneissic complex of granitic suite is the closepet granite.

Closepet granite seems to be intruded in the form of batholithic granite mass. It forms 15 to 70 kilometer wide linear belt extends in the north south direction for over 500 kilometers from closepet to Bellery districts of karnataka. The granite belt consists of multiple intrusion of differing characters. Porphyritic granite the most characteristic variety occurs as dome shaped discordant batholith surrounded by the finer grained gneissic variety. The porphyritic granite containing pink to grey porphyro blasts of microcline was formed by metasomatic replacement through the influx of potash rich solutions. Gneissic structure is seen almost everywhere and the inclusions and marginal rocks are related to the country rock on either side. The common rock are grey and pink porphylitic gneisses with large feldpars. The feldpars have gradually been changed from oligoclase to microcline while the petrographic types from trandjhemite through granodiorite to granite. Myrmekite is often seen while fine grained aplite is common.

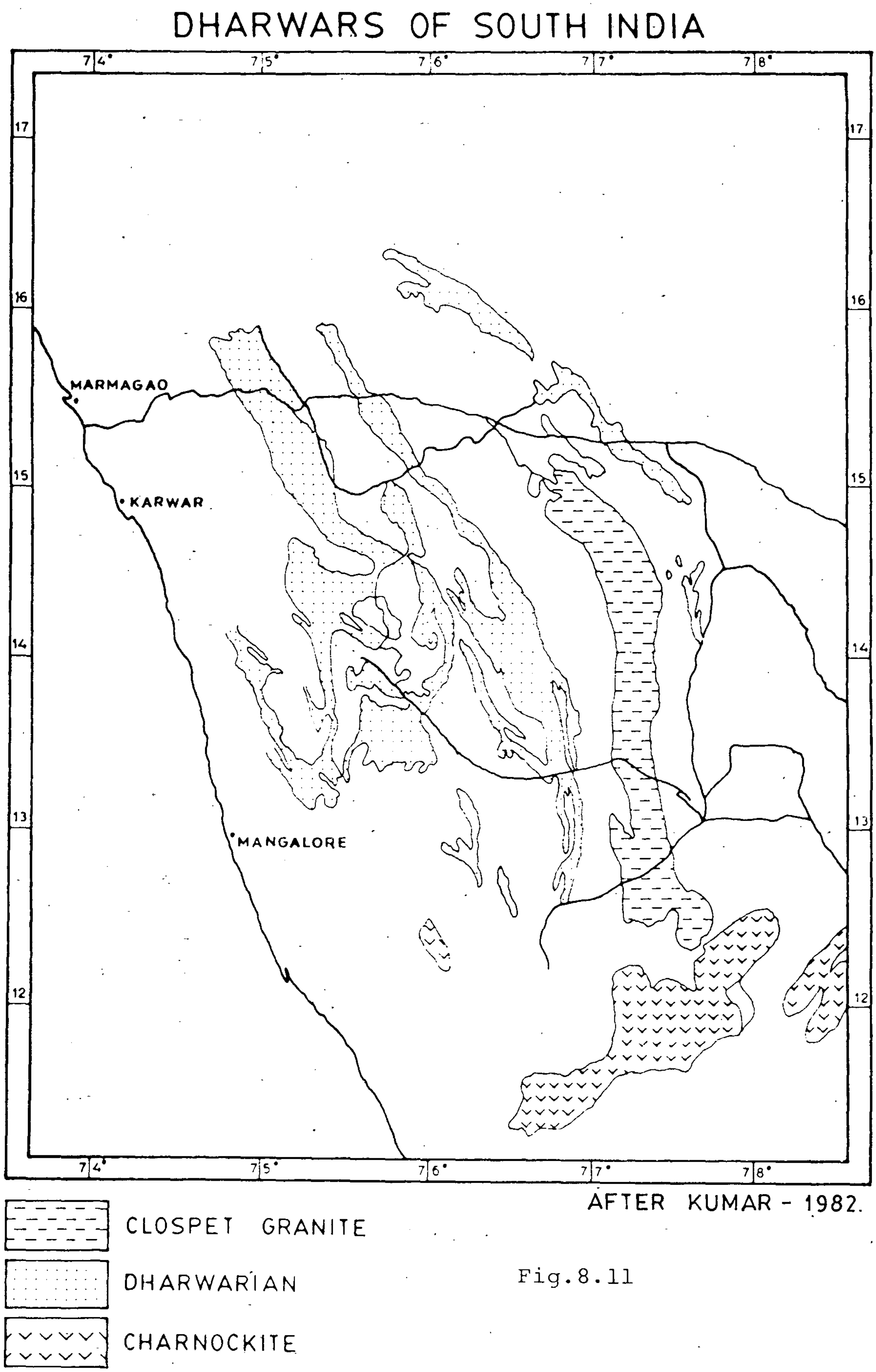

DHARWARS OF SOUTH INDIA
74°
75°
76°
77°
78°
17
16
15
14
13
12
MARMAGAO
KARWAR
MANGALORE
AFTER KUMAR - 1982.
CLOSPET GRANITE
DHARWARIAN
CHARNOCKITE

Fig.8.11

2100- 2380- M.Y.		Felsite and Porphysy dikes Closepet Granite
	---------------DHARWAR SUPERGROUP------------------	
	Raamnibennur Group	Magniferoms Phyllites Greywackes Chlorites Phyllites
	Chitradurg Group	Agglomerates, tuffs Pillow lava, Ferruginous magniferous Chert Dolomites and Limestones Phylites Orthoquartzites Conglomerates
	Bahabundan Group	Banded magnetite Quartizite, Argillites Mafic Lavas Orthoquartizites Conglomerates
	---------------UNCONFORMITY---------------------	
More than 2600 M.Y.	Peninsular Gneissic Complex	Granites and Gneisses Granites and Granodiorites
More than 3200 M.Y.	Sargur Schist	Magnetite quartizite, Schist granulite, crystalline Limestone and dolomite, mafic and ultramafic flows and anorthosite

Previously the Dharwar succession has been classified into two fold division the lover referred to as Hornblandic Division and the upper known as the chloritic division (smeeth 1916) Ramarao proposed a three fold division the hornblandic division of the smith was named as lower where as the upper chloritic division is divided into middle and upper Dharwar . Each division is said to be characterised by a conglomeratic horizon at its base. The lower unit comprises mafic to ultra mafic rocks of predominantly volcanic origin named as Bababudan group where as the upper unit is composed geosynclinal sediments with relatively reduced volcanic content named as chitradurga group. A still younger group, called Ranibenur group is mainly sedimentary in origin. Sedimentary origin socks comprises mainly orthoquartzites phyllites limestones dolomite banded ferruginous maganeferous quartzites, cherts and greywackes.

Since the closepet granite are batholithic types and is also associated with gneisses and schists thus the radiounclides which generally escaped through these fissure to microfissure should be incorporated into the surrounded matrix where they are effectively mobilized since this clospet granite succession are formed between 2100 and 2380 they will have cooled to the appropriate temperature so that the further joint formation appear to be unlikely. Secondly the zones is almost free from the effect of the known scismic activity so the fracture in the rocks are unlikely. [Krishnan, 1982].

This rock formation took place at relatively older stage the ground water in the granite would play the significant role and condition in the region. The region also seem to be associated with the surrounding aquifer as because surrounded by the sedimentary rock formation. The inter connection between the shallow as well as the ground water should be effectively studied.

It is also important to recognize that shallow & deep groundwater is granites may be in hydraulic conductivity and the heat generated by the deposited waste may give rise to connective circulation of groundwater moving deep water in the neighborhood of a waste repository towards the surface contrary to the pre waste disposal groundwater flow regime.

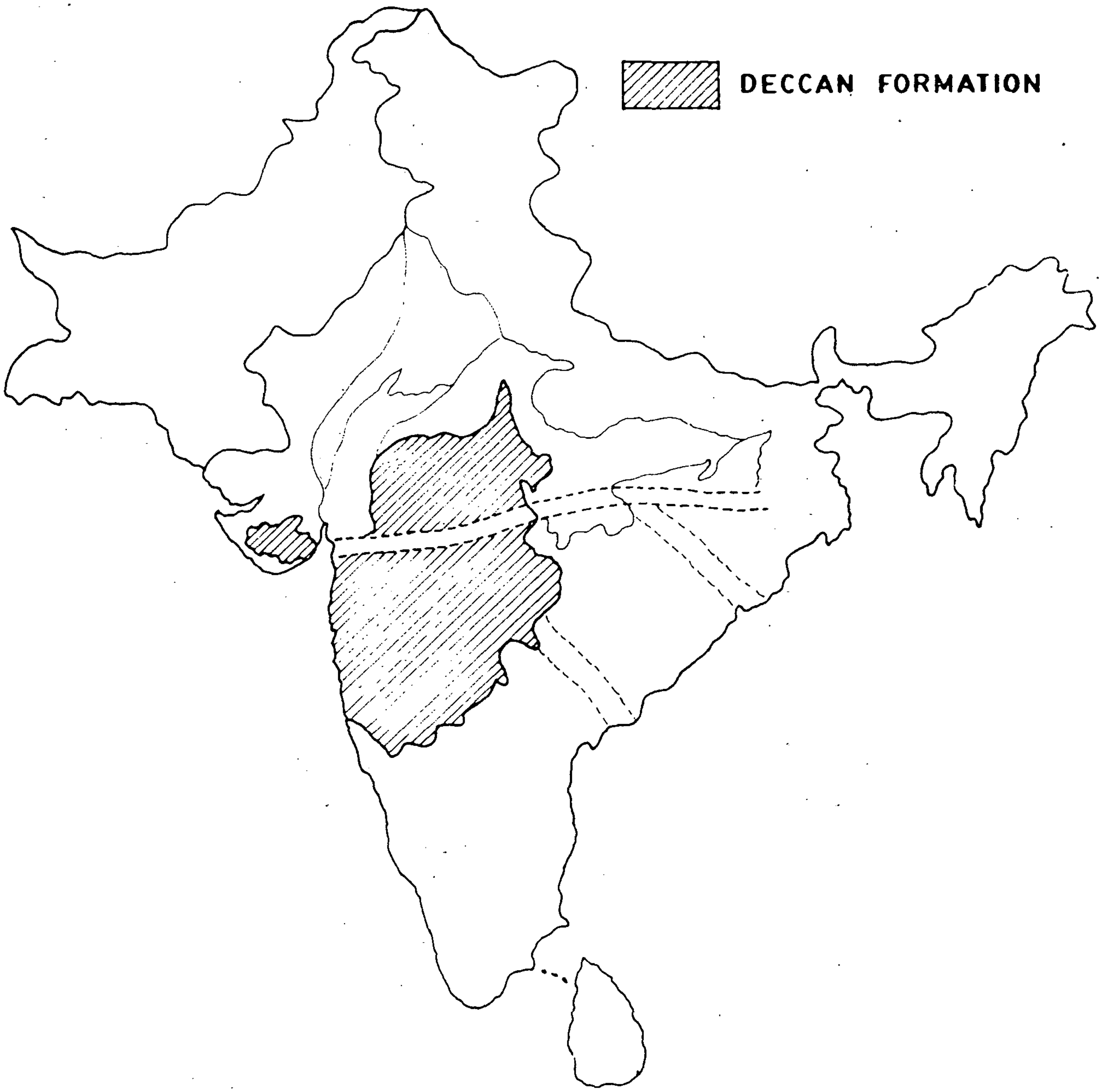
Since the heating can bring about annealing and repair radiation damage because of the volume change mineral in the immediate vicinity of a repository may be shattered with consequent alterations to be hydrogeological properties of rock Radiation can also change the atomic structure ands

this the density hardness and the other property of granite and that should be effectively checked.

8.5 HOST ROCK IN THE DECCAN TRAP

Basaltic and tuffacious rock due to their

CONSIDERED HOST ROCK IN DECCAN TRAP



TECTONIC MAP OF INDIA

AFTER KUMAR - 1982

Fig.8.12

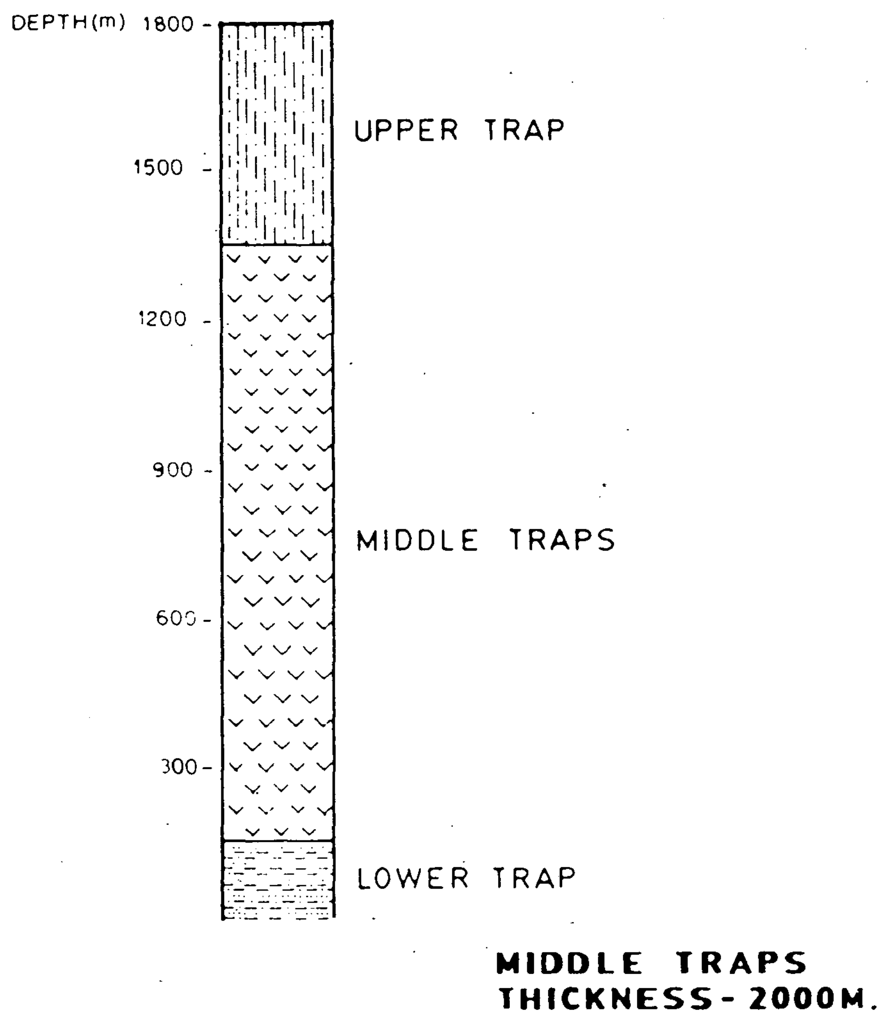
uniformity in composition and also due to their finess in the character has long been recognised as the potential site for the disposal of the above mentioned radioactive waste.

Deccan trap the enormous lava flow which spread over the vast areas of western, central and southern india,either through long fissures in the earth crust or through the crater i.e., the central type of eruption shows differentiated rocks of varying character. The area now occupied by the deccan trap is about 500.000 square kilometers including Bombay, Kathiawar, Kutch, Madhya Pradesh attaining a maximum thickness of about 2000 meters. This step like terraces is a result of the variation in hardness of the different flow, usually highly vesicular the middle fairly compact the bottom showing cylindrical pipes filled with the secondary mineral [Kumar, 1982]. The extra ordinary spread is due to a high degree of super heat in the errupted mass which is believed to have been derived from the basaltic or ecologitic shell of the earth & heat being due probably to exothermic material transformation. They are extra ordinary uniform in composition over much the greater past of the areas which composed of abundant labradorite of the composition An_{12} Ab_{42} and clinopyroxene i.e. usual dolerite and basalt . The secondary minerals are also developed in the traps which are due to the late hydrothermal activity such as zeolite bealandite heulandite, laumolnite, analcite, prehnite, together with calcite chalcedony & variety of agate jasper etc.

Together with the uniformity in mineralogical composition the chemical composition of the traps also tends to be uniform. The plateau basalt or the fissure eruption type when composed with the normal cone basalt or central eruption type show a higher iron and titanium content the iron being dominantly in ferrous state.

Primary mantle material presumed to be of the composition of garnet peridotite may yield two types of magma. The increase of the garnet constituent of original high pressure will give rise to the tholeiitic basalt at low pressure on the other hand by the increase of the omphacite constituent at high pressure & elmination of the garnet constituent will lead to the generation of the alkali-olivine type of magma. It would appears that alkali basalt type would be generated at a greater depth than the tholeiitic type hornblendic basalt(much water in the rock would produce hornblende rich) are rise in the Deccan trap [Krishnan, 1982].

Other important characteristic of Deccan trap which make it suitable for the radioactive waste disposal are the presence of inter trappean beds occur between the



STRATIGRAPHIC THICKNESS OF DECCAN TRAP

AFTER KUMAR - 1982.

Fig. 8.13

two successive flow. This inter-trappean succession would consist of black cherty detritus and carbonate deposits of lacustrine and fluviatile origin. The individual beds usually 1 to 3m thick extend laterally for 5 to 8km. The trap succession is classified into three stratigraphic succession the lower about 150m thick succession of trap with numerous inter trappean beds the middle unit comprising about 1200m thick lava flows & ash beds is practically devoid of inter-trappean beds and the upper unit of the succession consisting of about 450m thick sequence of lava flow practically consists of mumerous inter trappen beds which is exposed in the northwestern part of the peninsule

Following are the succession of Deccan trap

Upper traps - (450m thick)	With numerous inter trappean beds and layers of voleanic ash-exposed in Bombay and kattiawar
Middle traps- (1200m thick)	with numerous ash beds in the upper protions and practically devoid of intertrappeans - exposed in central india and Malwa region.
Lower trap- (150m thick)	with inter trappean beds but rare ash beds- exposed in Madhya Pradesh and eastern area.

Considering the hydrogeological condition,(that is the region which cantains numerous vesicular struture the stability of the region the quite unifornity as well as the finess in characters relative to granitic rocks are few important characterstic as well as very high thermal conductivity very high melting temperature and very high conpressive strenght would be taken into account before the disposal.

From thickness point of view the and the absence of intra-trappean sedimentary beds which shows the movement of hydrogeological water and the presence of ash formation which can act as the matrix for the released radionuclide less porosity and permeability the middle traps would be considered as the best suited repository site. The presence of zeolite and other such type of mineral would further approve this region for their suitability.

CHAPTER - IX

CONCLUSION

These would be description of the various geologically acceptable site area where the various type of radioactive waste may be disposed. But the final selection of sites would require knowledge of a number of disciplines. These includes many branches of earth science, engineering, safety analysis health physics, ecology, economic and the social sciences. The investigations will follow a detailed programme of theoretical, laboratory and field studies with significant interaction between the discipline.

Although each site must be considered on its own merits it is possible to list some of the general factors governing the suitability of the repository

(a) it should be possible to characterize the properties of the host rock in the vicinity of the repository

(b) The hydrogeological characteristic host rock and the ground water regime of the surrounding geological environment

(c) It would be advantageous if the host rock and/or the geological barriers can be used to retard the migration of radionuclides.

(d) The repository should be located at the sufficient depth in the host rock so that the waste would not be exposed to the biosphere until the radionuclides have decayed to insignificant levels.

(e) The repository should be constructed so as not to endanger the hydrogeological isolation of the waste.

(f) The acceptability of the geological formation should also be based on the extent of its occurrence and its economic value and finally

The site selection should be undertaken in close connection with the work for the repository concept and design and if necessary the introduction of engineered barrier should be taken into account.

Since it would typically concerned with the various types of host rocks such as Evaporites, Argiliaceous and Crystalline rock formations.

Evaporite having their ability of self-sealing tendency, particularly at higher temperature and their ability to cope with tensile and compressive stress can be considered as the fruitful point in the context of utilizing evaporites as HLW repositories. Although polyhalite and kieserite are unlikely to be suitable for high temperature repositories as they both lose water of crystallization at temperature between 300 and 450'C. Halite and anhydrite on the other hand owing to their anhydrous nature are not susceptible to change until much higher temperature are reached.

Evaporite to all purposes are impermeatble and simple presence of these highly soluble minerals goes some way to suggest that they are not generally associated with circulating ground waters. As it was found that halite can cause problem above 250^{o}C when rapid fluid decrepitation may occur. Thus it may be wise to suggest an upper design temperature limit of between 150 and 200^{o}C for evaporite repositories. The caution regarding the irradiation of the salt should also be taken into account. Although there is suggestion that dome salts may be quite stable. Yet but it would be practicably unavailable in the Indian context, nevertheless it remains important to be able to measure the existing and product future movement of the diapiric evaporites if these are to be considered for HLW disposal.

Taking the case of Argillceous formation as the host rock, the very plastic clays offer real advantage in terms of isolating buried waste from circulating ground water. It may not have the sufficient strength to facilitate the economical construction of the deep repositories.

On the other hand, the harder, stronger shales are more structurally stable, but the presence of a fracture porosity may cause a higher hydraulic conductivity and allow for the easier passage of groundwater.

As it was found that clays have relatively low values for the thermal conductivity compared with the other rock types, but on the other hand it has very high sorptive capacity. It needs to be remembered that sorption tends to decrease quite rapidly with rising temperature, a further reason to keep repository design temperature at or below 100^{o}C if possible.

And finally considering the Crystalline rock, it has generally been found that the Granites, basalts and tuffs can be assumed to be strong enough to support physical excavation and formation of suitable repository voids. Although it is necessary to recognize that granites vary considerably in their detail mineralogy and that a predominance of hydrous minerals in particular rock may render it liable to considerable change even at relatively low temperature. However the design temperature of a repository in granite and other crystalline rock should be kept below 200^{o}C and ideally lower than this.

The fracture dominated nature of most crystalline rocks makes on appreciation of their hydrogeology very difficult to realize. It is particularly the case with respect to the layered nature of many basalt and tuffs. The effect of thermal stress and other stress factors associated with the excavation of the rock itself can further complicate the nature of the fracture dominated flow paths in the immediate neighbourhood of the crystalline rock repository.

So the temperature should be taken into major consideration. It should not be more than 200^{o}C.

Taking the other chapter into consideration it has been found that other major factors for the disposal of high to low grade radioactive waste, the topography, the Geology, the Geohydrology the hudrology and Geochemical aspect should be given the special interest.

Lastly taking the conditioning and packaging of the radioactive waste, case should be given on the packaging and the economical condition of the type in which it should be shield.

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