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Component-I (B) Description of Module

Items	Description of Module
Subject Name	**Geography**
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Weathering: Scale, Types and Classification

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The objectives of present module are as follows::

1. What is weathering?

2. Weathering Grades

3. Physical Weathering Processes

4. Chemical weathering Processes

5. Biological Activity and Weathering

6. Significance of Weathering

7. Features formed due to Weathering

1. What is weathering?

Weathering is the first stage in the **denudation (wearing away)** of the exposed landscape. **It is a process by which surface and subsurface rocks break up, dissolve, and decompose**. All weathering activity occurs on the spot (*in situ)*. Since Weathering disintegrates, dissolves, decomposes the rock, it facilities the movement of rock debris by mass wasting. It is a part of ***exogenic process*** because it directly and indirectly derives required energy from insolation, which guides systems above the surface of the earth, including the atmosphere. Weathering is also an important process of earth system because it facilitates in the formation of mineral and soil development. 60 per cent population of our country is directly and indirectly dependent on agriculture which is to a great deal dependent on soil.

Definitions

"Weathering—the physical breakdown (disintegration) and chemical alteration (decomposition) of rocks at or near Earth's surface" (Tarbuck, Lutgens and Tasa, 2012).

"Weathering is in situ disintegration and decomposition of rocks into a residuum of original matter and alteration products in equilibrium with the stress of the environment." (Sharma, 2010).

Weathering may be defined as the disintegration or decomposition of rock in place. It is really a name for a group of processes which act collectively at and near the earth's surface and reduce rock masses to the clastic

state. It is a static process and does not involve the seizure and removal of material by a transporting agency. (Thornbury,1993).

2. Weathering Grades

We can also identify the different weathering grades of rock.. Stage wise there are six grades of weathering. **"**Weathering grades of rock" ranges between fresh weathering grade to residual soil (Figure 1). The fresh grade exhibits no visible sign of rock material. The slightly weathered stage is identified by discoloration of rock. When less than 50 per cent rock material is disintegrated or decomposed in a soil it is called moderately weathered stage in relation to present grade. In the highly weathered category more than 50 per cent rock material is disintegrated or decomposed in a soil. In the last and final stage all the rock material is converted to soil which is known as residual soil.

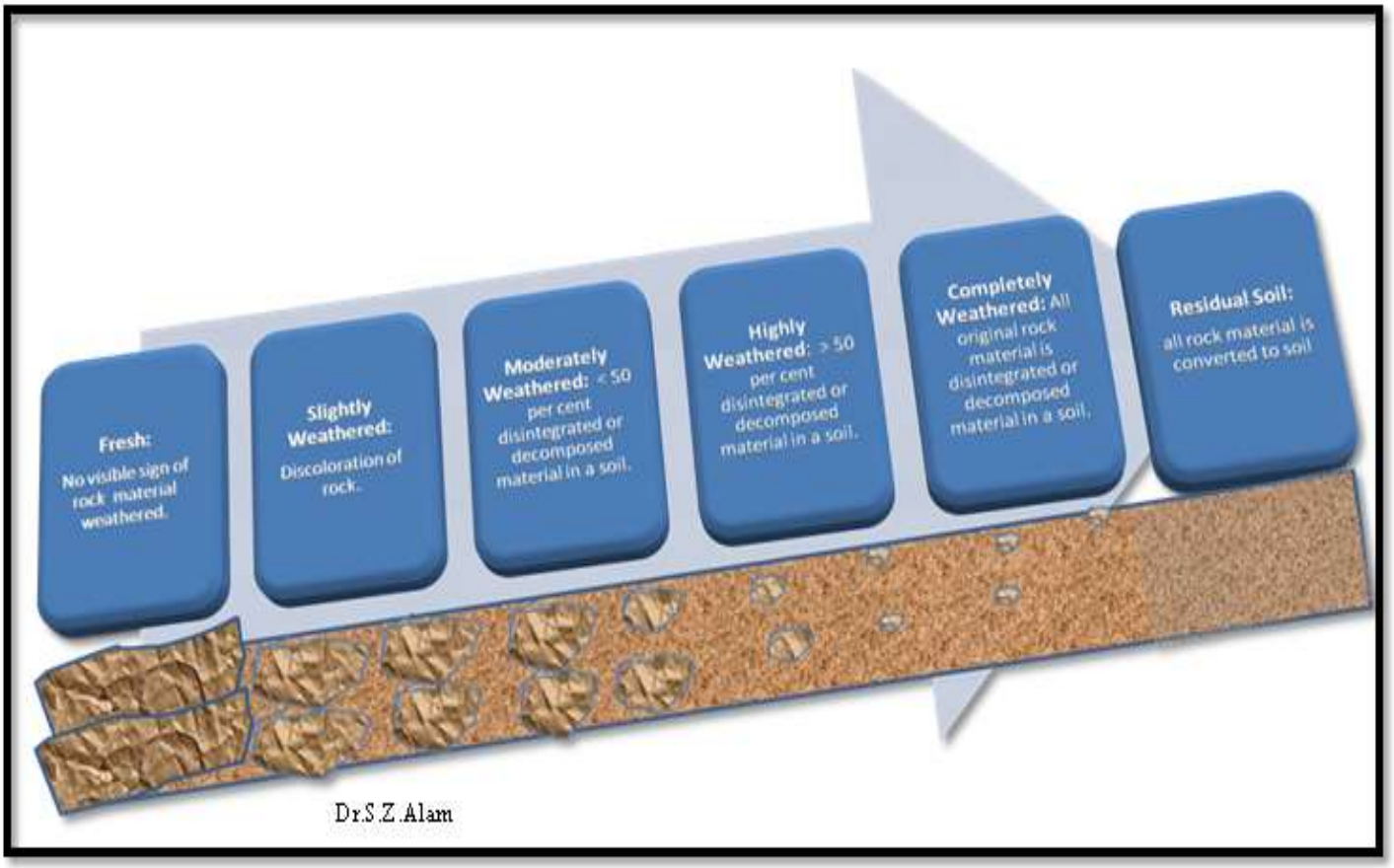

Figure 1: Scale of weathering grades of rock.

It is important to note that the rate of weathering depends on property of **parent rock** (mineral solubility and rock structure), **climatic conditions** (frequency of frost, rainfall, temperature and length of exposure to sunlight). The presence of **organic activity** in the soil also influences the rate of weathering. Weathering processes are largely determined by the **climate and vegetation of a place**. Dry locations are largely influenced by physical weathering and moist places by chemical weathering.

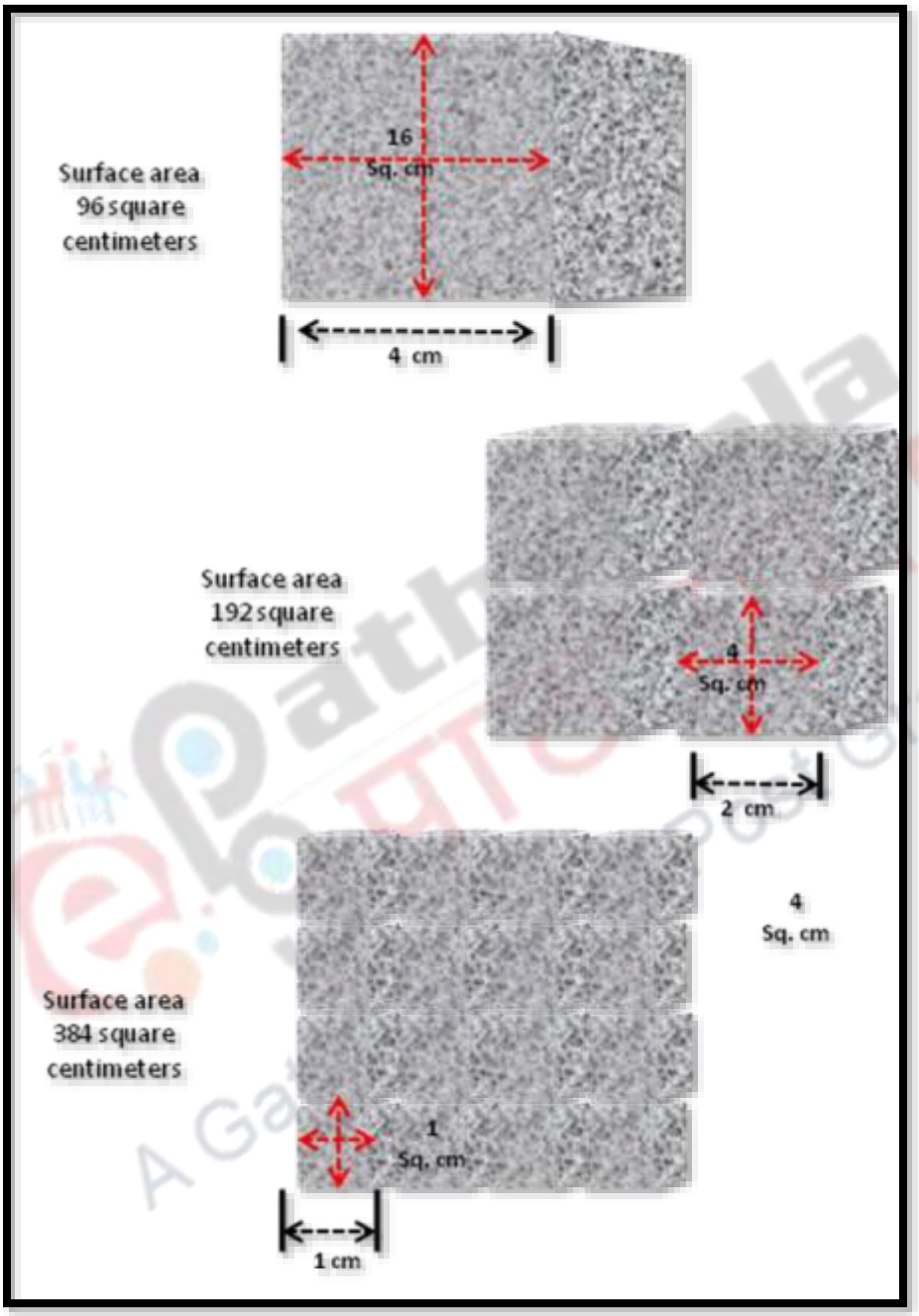

Figure 2: The physical weathering generates smaller pieces or rock which in turn produces additional surface area for chemical weathering.

In general there are three **types** of weathering: **mechanical, chemical and biological weathering**. Mechanical weathering denotes the breakdown of rock without any conspicuous degree of chemical change in the minerals of the rock. Chemical weathering involves the decomposition of rocks in which decay of minerals are recorded. It is important to note that in real world mechanical and chemical weathering process may operate

together though in differing proportions. Biological processes also contribute to weathering. The biological weathering is any type of weathering that is caused by living organisms.

3. Physical Weathering Processes

The process by which a rock or **mineral is broken down into smaller fragments without apparently altering its chemical composition** is called physical weathering. It transforms rock by breaking it into smaller fragments. This transformation takes place through mechanical methods such as freeze-thaw, salt weathering and thermal cracking. In the process of physical weathering the forces which break the rock may also originate within the rock or mineral, while others may begin from outside the rock or mineral. Both of these stresses lead to strain and the rupture in the rock but without any conspicuous change in the chemistry of the rock material. The activity of physical weathering breaks large pieces into smaller ones. Figure 2 shows that these smaller pieces create additional surface area for chemical weathering (figure 2). The broken or detached fragments of rock are called **clasts**. The action of physical Weathering is more apparent in deserts, high mountains and arctic regions (Waugh, 1990)

There are several types of Physical Weathering Processes. For example, Frost wedging is more noticed when accumulated water in a fractured area freezes and creates pressure in the rock. Diurnal Temperature changes in places like hot deserts may cause rocks to break apart. Tree-root wedging may also enlarge cracks in rock. Similarly in dry climatic region, salt crystallization aids to split the rock. The cracks may also develop in the rock mass due to unloading of deeply buried rock by erosion of the overlying layers and consequent isostatic expansion of rock mass.

Freezing, Thawing and Frost shattering

Generally most substance expands when they are heated and they also contract when they are cooled down. But water is an exceptional wonder molecule unlike any other substance which expands when it freezes. The total expansion of water is about **9 per cent in volume at 0°C**, and further to **13.5 per cent at −22°C**. It is also noteworthy that this expansion is also responsible for the bursting of water pipes in the polar and sub polar regions. The water in the form of ice crystals can generate very strong **cryostatic pressure** (Outcome of weight and thickness of the ice) of 2100 kg cm−2 against the hollow cracks, crevices and joints in the rock. In cold climatic region rocks contain small cracks, which are sometimes filled with water during the day time or in summer season. Water in these cracks expands as it freezes. If cryostatic pressure exceeds the tensile strength of the rock, the rock breaks. This entire mechanical process is known as frost action or frost shattering (**Figure 3**). Frost shattering is one of the most effective processes in the polar and sub polar region. Frost shattering creates widespread disintegration of the rock along its prearranged structural weakness present in the rock. Frost shattering is most effective in rocks containing numerous fractures or bedding planes (Thornbury, 1993). The **block disintegration** on steep hilly slope ultimately produces scree and talus at the foot of the hill. In areas having gentle slope the frost shattering produces bulky **blockfiled** which is also known **felsenmeer (**German meaning 'sea of rock') and everest (Figure 4). Blockfileds look like sea or streams of angular rocks. But they are different from screes and talus.

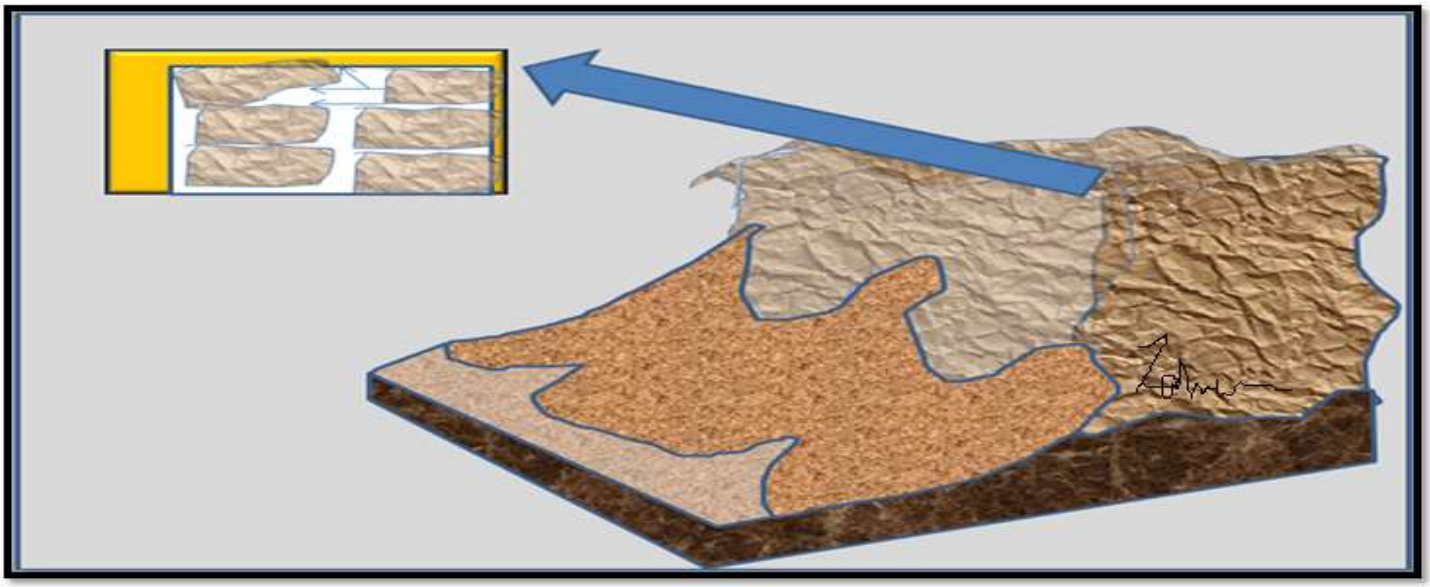

Figure 3: Frost wedging. As water freezes it expands, exerting cryostatic pressure great enough to break rock.

Figure 4: Blockfileds.

Expansion resulting from Unloading

The release in pressure in the rock can cause physical weathering. It happens due to removal of overlying material by erosion. This process is known as unloading. In this process the rocks ***isostatically*** and elastically compensate for the erosional loss of mass by expanding perpendicular to the direction of pressure release. This unloading of pressure causes the rocks to fracture horizontally (**Figure 5).** The number of fractures increases as the rock approaches the Earth's surface due to unloading process. The horizontally arranged fractures are also called sheet fracture or **sheeting (Figure 6).** In Italian Alps region many sheet fractures have developed after Pleistocene glaciations which are attributed to isostatic rebound (Kiersch, 1964). The weathering of granitic monolithic rock due to Unloading and Expansion **in Bhuvangiri town** (Andhra Pradesh) has also formed rounded dome shaped masses called ***exfoliation domes*** or onion peeled domes. Many such domes are also found in the Sierra Nevada range in California in United States, Stone Mountain in Georgia, Half Dome in Yosemite National Park (Petersen, Sack and Gabler 2011).

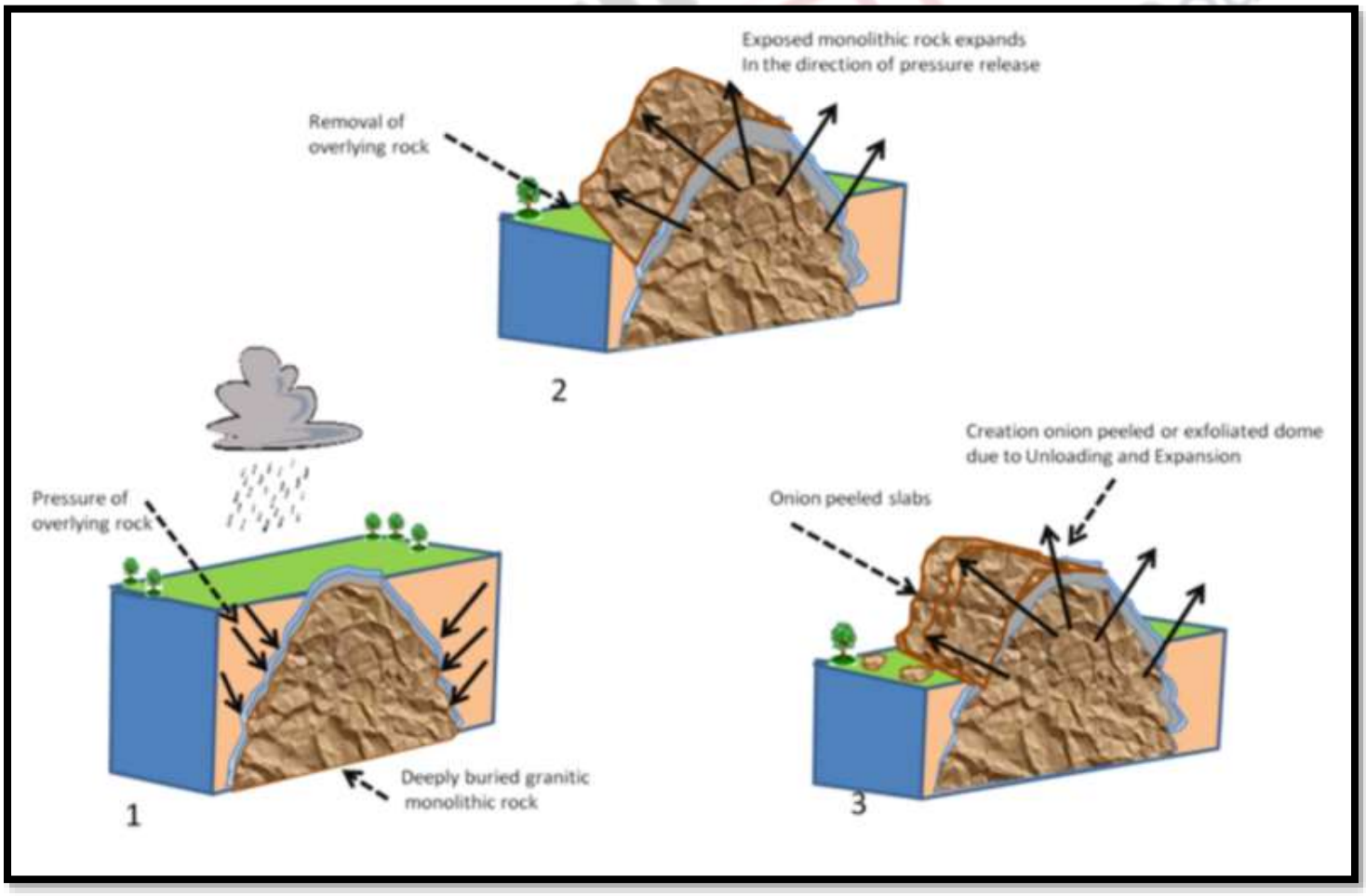

Figure 5: Weathering of granitic monolithic rock due to Unloading and Expansion

Figure 6: Sheeting in Vindyan ranges, Mirzapur, Uttar Pradesh.

Thermal Expansion and contraction or Insolation Weathering

In desert regions of the world the large diurnal temperature changes are mainly responsible for mechanical weathering. We know that the rocks are composed of many mineral suites having varying physical property in terms of absorption, conductivity, and retention of heat. These unique properties of rock result in **differential rates of expansion and contraction** of rock mass. The surface of the rock expands more than its interior part, and this expansive stress ruptures the rock. The **variation in the colors** of mineral grains present in rock may also cause differential expansion and contraction of rock mass in terms of its volume. It is also important to note that the dark colored grains, because of their absorptive properties, will expand much more than light colored grains. Therefore ultimately the rock disintegrates along the boundary of mineral grains. This process is also known as **insolation weathering**. In desert environment the moisture in form of dew creates cycle of hydration and dehydration of minerals which ultimately weakens the rock fractures for insolation weathering. In context to insolation weathering it should be noted that the laboratory experiments by G.T. Griggs raise a doubt upon the effectiveness of thermal expansion without the presence of water (Waugh, 1990).

Crystallization of Salts

Salt weathering represents mechanical weathering of rock because **no conspicuous chemical alteration** of rock constituents is involved in this process. The saline water found in pore spaces evaporates during the high temperature i.e., during the day time or in dry conditions. It leaves behind the salt crystals in the rock's small opening. The expanding salt crystals exert a pressure on the walls of the host rock pores that exceeds the **tensile strength** (The ability of a material to withstand tension) of the rock. This process of falling off of individual grains may result in granular disintegration or granular foliation of rock generally effective in coarse

crystalline igneous rocks. The magnitude of this stress, however, varies with the composition and concentration of ionic species, and the manner of crystallization at and within the impacted surfaces (Smith, 1994). The salt in the rock pores may also come from biochemical activities, **capillary action**, and airborne dust. In areas with alternating wetting and drying condition favors the growth of salt crystal. Therefore, the neighboring grains are pushed aside. Sodium chloride and gypsum crystals in desert areas lift overlying layers of materials which results in cracks in host rock. With salt crystal growth, chalk breaks down most readily, followed by limestone, sandstone, shale, gneiss and granite. For example, The capillary salts, including nitrates and nitrites, have caused extensive scaling, crumbling, and discoloration of the outer and inner building materials of the **Islamic monuments** of **Khiva and Bukhara in Uzbekistan** (Akiner, Cooke, and French, 1992).

4. Chemical weathering Processes

Chemical weathering decomposes the rock and creates a **new chemically different material** that has undergone weathering. The tendency of the minerals to strive for equilibrium with the environment is called chemical weathering (Sharma, 2010). In general, it is probably true that chemical weathering is more important than physical weathering ((Thornbury, 1993).) Several chemical reactions occur in the Earth-surface environment. In order to understand chemical weathering we need to know the 'raw materials' for chemical reaction found in the rocks found on the earth and Earth-surface environment. The **main agents** involved in chemical weathering are as follows:

- Oxygen, carbon dioxide and other gases from the atmosphere;
- Water from precipitation in the form of rain and snow; and
- Minerals present in the rock composition.

Rocks can be composed of a single type of element, or more than one element. These composite substances are known as minerals. Minerals are chemical substances found in the rock. Some minerals like gold or silver are made of only one element. Other minerals, like quartz and calcite, are mixtures of two or more elements. It is important to note that, **internal structure of minerals is the main factor**, **which controls all sorts of chemical and physical properties of any rock**. In reality a mineral structure is a molecular structure which is determined by the sizes of the atoms found in the minerals and by their charges and electron configurations. For instance, diamond and graphite have exactly the same chemical composition, but the carbon atoms are arranged differently and held together by different types of bonds. **The strength of the bond** largely determines chemical alteration of minerals through chemical reaction.

During chemical weathering, **the internal molecular structure of a mineral is altered** by reaction with other elements. For example, dissolved oxygen in water has potential to oxidize minerals that contain **iron,** this process is known as oxidation. Similarly, Carbon dioxide dissolved in water forms creates carbonic acid that can effectively dilute limestone or change the feldspar in granite into clay minerals. This process is known as carbonation. In hydrolysis process pure water can also combines with some minerals to form new by-products. Water may also soften some minerals through its dissolving capability (solution). Salient types of chemical weathering are as follows:

Oxidation and Reduction

In chemistry oxidation does not necessarily imply oxygen, but simply the **loss of electrons**. It involves a chemical reaction with oxygen. The burning of wood or paper occurs due to oxidation process. The oxidation is an important part of our kitchen i.e. when we cook our food oxidation process is always there by assisting burning process. Conspicuous example can be given from **rusting** of a mineral. In Earth-surface environment, the element that is most prone to oxidation is iron (Fe). Most of the minerals found in igneous and metamorphic

rocks contain **Fe2+ ions** which react with the oxygen. The signs of oxidation can be noticed in shallow water bodies and aquifers carrying organic matter.

Solution

Solution is generally the **first stage** of chemical weathering. It can take place in a thin film of water around a solid particle or in running water. A solution is a homogeneous mixture in which one substance called the ***solute*** is dispersed in another substance called the ***solvent.*** The solutions are everywhere around us. The air we breathe is a solution that is chiefly oxygen and a nitrogen gas. The Ocean is also a solution, consisting of many salts such as sodium chloride dissolved in water. The Pure water is also an effective agent in dissolving some minerals. The water can dissolve soluble rock-forming minerals and **break down the molecular structure** of certain minerals. The dissolved salt may also form salt crystals to facilitate physical withering mechanism indirectly. Solution tends to be most effective in areas that have **hot humid climates**.

Do You Know?

Soil Collides may have the power to loosen or pull off small bits of rock from the surfaces with which they come in contact. This weathering process of uncertain importance is called *collide plucking*. (Thornbury, 1993).

Carbonation

Carbonation is the reaction of **carbonate and bicarbonate** with minerals. The formation of carbonates usually takes place as a result of other chemical processes. The atmosphere contains carbon dioxide (CO2). When rain falls, water and carbon dioxide combine (CO2 + H2O = H2CO3) and forms carbonic acid that is H2CO3, which in turn helps in **dissolving minerals**, particularly those susceptible to weak acids, such as calcite, dolomite, and marble. Carbonation is especially active when the reaction environment is abundant with carbon dioxide. The carbonation process is especially active in **karst regions** of the world. The solubility of karst relies on the volume of carbon dioxide stored in karst systems.

Hydration

Hydration actually denotes **addition of water to a mineral**. It denotes chemical combination of water molecule with other mineral substances. According to Petersen et.al (2011) in weathering by hydration, water molecules attach to the crystalline structure of a mineral without causing a permanent change in that mineral's composition. The water molecules are able to join and leave the "host" mineral during hydration and dehydration, respectively. In many situations the **H+** and **OH ions** (An atom, molecule or compound that carries either a positive or negative electrical charge) become a structural part of the crystal lattice or network of the mineral. The hydrated minerals expand many times the volume of their original state which creates mechanical stress in rock to disintegrate. The cycle of hydration and dehydration in minerals further boosts the **stress mechanism** eventually breaks the rock. Hydration also accelerates decomposition reactions by expanding the crystal lattice (network), which in turns **creates more surface area** for further reaction and extra surface area for physical weathering. Iron oxide, for example can absorb water and turn into hydrated iron oxides or iron hydroxide.

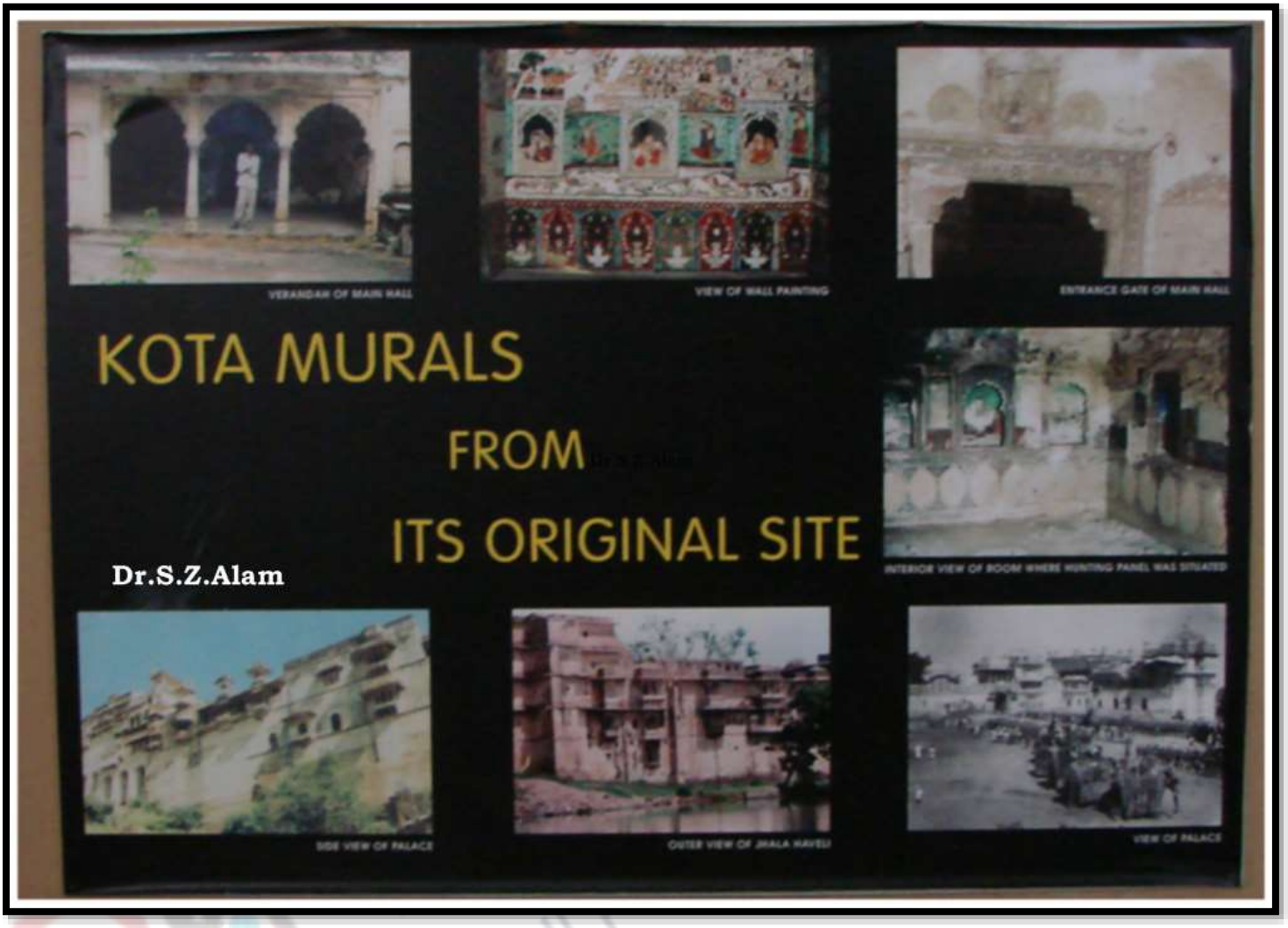

Figure: effect of various types of weathering on monuments (National Museum).

5. Biological Activity and Weathering

The word 'bio' means life. Thus biological weathering is any type of weathering that is caused by living organisms. The biological weathering has common characteristics of both physical and chemical groups of activities in disintegration and decomposition of rock.

Role of plants and animals

For example, Plant roots penetrate into cracks in rock and slowly break the rocks apart mechanically. The roots of the plant also secrete certain chemicals to extract minerals, thereby causing chemical weathering. The major weathering agents produced by plants include CO2, organic acids, and ligands (Kelly, Chadwick and Hilinski, 1998). The ***chelation*** is an important biochemical process generally occurs in the **roots of the plant**. The *chelation* breaks down the mineral structure by dissolving and dislocating metallic and nonmetallic minerals which in turn reduces the toxicity in natural ecosystem. The specific process or set of plant related weathering positive feedback processes may increase weathering, whereas negative (-) feedbacks are likely to decrease weathering. The growth of plants on the upper portion of the historical ***Bharateswara*** **temple** has deteriorated the condition of the temple (Bhargav, Mishra and. Das, 1999).

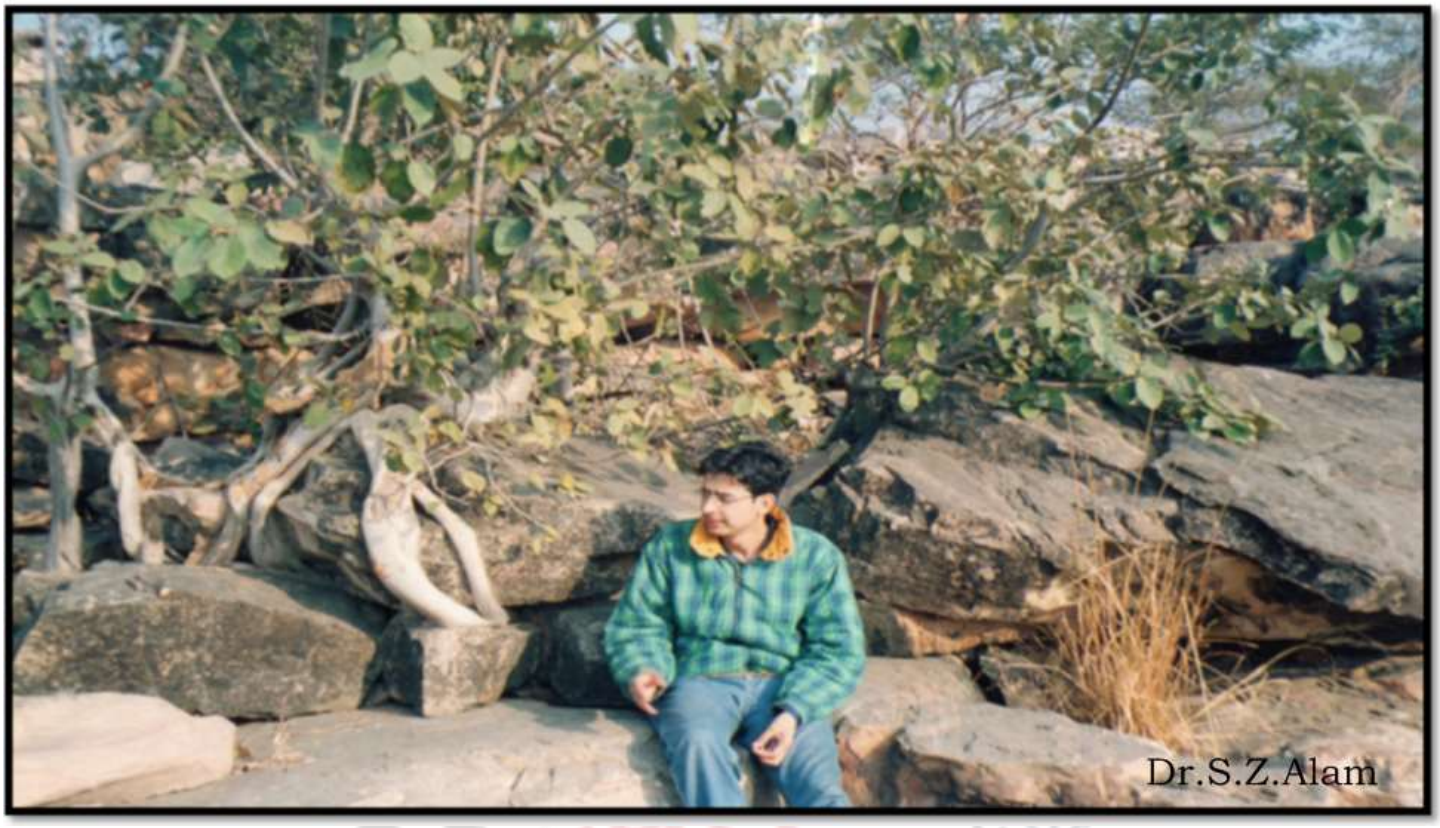

Figure: Plant root exerting pressure along the weaker portions of rock. Location Mirzapur Uttar Pradesh (Field Survey)

Animals and insects that den/nest/cave into soft rocks are also mechanical weathering agents. The **earthworms** are found in most of the moist parts of the world with the exception of extreme temperatures. They till, aerate and decompose the soil minerals. Similarly, **termites** and **ants** found in loose minerals of the soil are responsible for underground constructions. **Many animals in the world dig up the earth for a variety of reasons**: to dig up food, either floral or faunal; to cache provisions; and to excavate habitations. **All above mentioned activities help in exposing the new surfaces to chemical attack.**

Figure: The work of termites in the Surai forest region in Uttarakhand. (Field Survey)

Anthropogenic activity

One of the most effective agents of biological weathering in the present time is the human beings. Mining and quarrying, highway construction projects and excavations for building foundations and basements all lead to significant weathering of the surface of the earth.

Figure: Weathering by human agency: Construction of Delhi Metro along the National Highway number 1, Jasola, Delhi.

6. Significance of Weathering

Weathering is an important mechanism which weakens surface materials. This process is in turn is helpful for their eventual removal of material by **erosion processes**. It contributes to the **formation of soil** by providing mineral particles like sand, silt, and clay. The weathered rock fragments in the form of deposits make fertile plains, beaches and sand dunes. The weatherings of minerals (from rocks) are of great importance for the **economy of any country**. The minerals created by weathering processes supply nutrients for **plant uptake**. Weathering liberates chemical compounds which are directly and indirectly helpful to **suppress toxics** created in the biosphere. Therefore, weathering is a process that is essential to many other aspects of the hydrosphere, lithosphere, and biosphere.

7. Features formed due to Weathering

1. Weathering is an important process of earth system because it **facilitates mineral and soil development**. 60 per cent population of our country is directly and indirectly dependent on agriculture which is to a great deal dependent on soil.
2. The **block disintegration** on steep hilly slope ultimately produces **scree and talus** at the foot of the hill. In areas having gentle slope the frost shattering creates bulky **blockfiled** also known **felsenmeer (**German meaning 'sea of rock') and everest. blockfileds look like sea of angular rocks which is different from screes and talus**. (due to: Freezing, Thawing and Frost shattering)**
3. **Sheeting:** The horizontally arranged fractures perpendicular to the surface of the earth are also called sheet fracture or **sheeting (**due to Unloading and Expansion)
4. The weathering of granitic monolithic rock due to Unloading and Expansion **in Bhuvangiri town** (Andhra Pradesh) has formed rounded dome shaped masses called ***exfoliation dome.*** **(**Due to Unloading and Expansion)
5. The capillary salts, including nitrates and nitrites, have caused extensive scaling, crumbling, and discoloration of the outer and inner building materials. (due to Salt weathering)
6. The carbonation process is especially active in karst regions of the world.
7. Hydration also accelerates decomposition reactions by expanding the crystal lattice (network), which in turns creates more surface area for further reaction and extra surface area for physical weathering.
8. It facilitates to the development of **tors**
9. **Spheroidal** boulders due to repeated thermal expansion and contraction of rock surfaces.

Thank You