4. CONCLUSIONS

1. Analysis of mud mortar and its composition at Ajanta, support the short chronology since it is assumed that in last 200-300 years, there may be some changes either in composition or technology of preparation of mud mortar/execution technique. Moreover, organic binder has invariably been used in the preparation of mud mortar in accordance with ancient text which have now transformed into calcium oxalate, observed through FTIR images. The plaster is also found to be mixed with organic additives such as rice husk, plant fibers & seeds for re-enforcement and to prepare mortar without any cracks and shrinkage. With minor variations, almost similar technology was used for the preparation of mud mortar of each cave and pigment layers were also found mixed with organic binder and sometimes with kaolin as per ancient text. With minor modification, the technique of painting at Ajanta remained almost identical and the pigments used are always natural mineral colors. All the pigments are of local origin except lapis lazuli which was probably imported from Persian countries through trade on silk route. The studies are of great importance in planning future conservation measures of Ajanta murals and understanding of execution technique.

2. The excavation of Ajanta represents extraordinary rock architecture in western Deccan after about three hundred years of abandonment in rock art. It seems, technicians has avoided a massive basalt trap full of flaws as much as they could in choosing cave site. As mercantile and royal endowments grew, cave interiors became more elaborate, with interior walls decorated with murals and intricate carvings. The technique of mural paintings was copied from Ajanta and taken to south-east Asia where many Buddhist countries represented India’s great material culture. Application of varnishes for copying and general conservation poses problems for mural paintings.

3. On-site, Raman spectroscopic studies carried out on the pigments used in the paintings in three of the rock shelters of Bhimbetka using portable equipment and the investigations done using laboratory equipment on extracted fragments of the
pigments have revealed the presence of minerals such as calcite, hematite, gypsum, whewellite, and goethite. An evidence of the presence of a possible organic binder is also found in one of the extracted pigment sample. This is the first report of any on-site Raman study on a pre-historic site in India that contains rock paintings starting from the period of the cave dwellers to recent times. The background due to ambient day-light illumination appears to be a serious limitation in on-site studies.

4. The scientific analyses carried out in Ajanta cave 17 by non-destructive and destructive techniques evidenced that the paint layer has been applied onto dry plaster with pigments of inorganic nature. Some differences in the pigments used and in the style of painting were evidenced between the different walls of the cave, suggesting the presence of different artists. The pigments used at Ajanta consist of red pigments used are red ochre, red lake, cinnabar, minium. yellow and orange pigments are yellow ochre, orpiment and/or realgar and a yellow organic dye. Kaolin, calcium carbonate, shells white and lead white were used as white pigments. Blue areas were always painted with lapis lazuli, black areas with an organic black. Green areas were painted with green earth or with a mixture of orpiment and green earth and/or a pigment of organic origin. In the paint layer, pigment is mixed with kaolin and often also with gypsum. The binder is certainly of an organic nature and it is probably a vegetable gum. Two preparatory layers are present: i) a preparatory layer constitutes of mud, vegetable fibers, dung and grinded local rock; ii) a calcium carbonate preparatory layer, which probably has the function of rendering the pictorial surface flat and homogeneous in color in order to better receive the pigment layer. The pictorial surface is covered with a thick layer of different superimposed materials such as lamp black or charcoal, calcium oxalate, altered shellac, oil, natural resins, polyvinyl acetate. The presence of such a large variety of superimposed materials sometimes do not allow the clear reading of the details of the paintings and renders particularly difficult the cleaning operations.

5. With increasing population, the cave murals of Ajanta in combination to other factors are also being affected on account of visitor’s impact in the form of rise in humidity, temperature, carbon dioxide content, dust fall etc. Experiment carried by monitoring the environmental parameters inside the cave clearly shows 7-8% increase in humidity when more that recommended 40 number of visitors enter
the cave at one time. Similarly, increase in carbon dioxide content has also been observed with increase in numbers of visitors causing long term effect on painted surface. Besides the use of eatables by some visitors inside the cave give rise to food chain for insects. Archaeological Survey of India has given top priority for the conservation of Ajanta murals and has taken many steps for proper visitor management.

6. Microclimatic conditions constitute a critical factor in the conservation of cave paintings of Ajanta (2nd century BC to 4th century AD), a World Heritage Site in India. The monitoring campaign carried in cave no. 2 of Ajanta include recording data for relative humidity, temperature, CO$_2$ content at different locations inside the cave, and the impact of more than the recommended number of visitors on cave environ and noise level. The fluctuating hygrometric condition and thermal stability of cave no. 2 were compared to the most ancient cave no. 10 situated in the middle of the crescent-shaped scrap of basaltic hillock. The comparatively drastic environmental condition of cave no. 2 has caused severe problems of conservation of murals in the form of detachment of paint layer, falling of the white pigments, and formation of ridges, cracks and gaps in the painted plaster. The lower painted wall surface shows high humidity with increased conservation problems. The CO$_2$ content is quite high in the central hall of the cave due to exhalation by visitors. The low permeability shellac varnishes applied in 1920 have hindered the breathability of the paint layer.

7. The low permeability of painted surfaces, due to the old protective layers, inhibits microbial growth but, on the other hand, these old treatments alter the chromatic perception of the paintings also. With a focus on a future restoration intervention, the environmental study has highlighted two main critical aspects: i) the cleaning phase, with the removable of the old protective layers, and ii) the restoration phase, with the choice of the materials and products. In fact, the variation of permeability of the surfaces could trigger chemical, physical and biological decay phenomena.

8. From the review of the previous conservation treatments, it is observed that many physico-chemical conservation measures were carried out at Ajanta by International/ Indian conservators to evolve suitable mythology for painting conservation. The work carried out by various agencies at Ajanta has now been
compiled during this research project for the benefit of future conservation intervention.

9. A few sq.mt. 2nd BCE painted plaster still surviving in cave no 9 and 10, Ajanta pose most difficult task of cleaning the historic surfaces. The paintings diagnosed to be executed on a very thin lime plaster ground with inorganic colors by portable XRF; the FTIR spectra of the pigments and lime ground denote that varnishes have seeped through due to its repeated application in the past. The usual organic solvent mixture technique being used as well as the micro-emulsion technique applied for cleaning proved non-effective in the treatment of that part of the paintings covered with thick bats excreta.

10. From the scientific conservation of Hinayana paintings, cave no.10, Ajanta the following conclusions were drawn:-

1) The surface of the outer layer of lime plaster ground is very thick.
2) The background of the color is very simple and undecorative.
3) Maximum cracks and crevices are noticed wherever white color has been applied in the painting.
4) Lower lips of some of the human figures are in red colour, which is very sensitive as compared to other colours.
5) Most of the human figures are painted in yellow colours.
6) All the figures’ outlines have been drawn in black colours of equal thickness.
7) Green pigments are always found less adhering than any other pigments.
8) From our experimental work, it was observed that the removal of accretion from white coloured surface is easier to any other colour.
9) Black outline is very thin and in contrast to cave no. 17 painting very less sensitive to cleaning solvent mixture.

The panel painting is being observed after this experimental treatment and the work will be extended to other part of the panel after strict monitoring and discussion.

11. The Hinayana wall paintings have been exclusively done on lime plaster, as compared to Mahayana paintings, which were executed either on mud or lime plaster ground. The Hinayana painted figures are always small with sharp outlines, good depth and excellent physical proportions. The colours applied are mostly yellow, red, and green ochre of opaque characteristics. The stone carrier
of Hinayana paintings has a smooth surface and the lime layer applied on it is very thin. The Wheel of Law is not fully round but has a slightly oval shape.

12. The earthen plaster of Ajanta is characterized by high silt and low clay content, the raw material for which was most probably sourced from alluvial soil bed of Waghura River and characteristics modified by addition of organic additives and vegetal matter. The addition of gluconites and zeolites in the earthen plaster as aggregate is a unique feature. The earthen plaster is also characterized by deliberate addition of calcite to modify the properties of raw material and enhance its binding properties. It may be concluded that the addition of sepiolite may be intentional to enhance the performances of the mud plaster. This characterization has helped in the preparation of new earthen materials for conservation efforts at Ajanta for better compatibility and optimum performance.

13. The particle size distribution curve of mud mortar and local raw soil demonstrate the exploitation of closely related well graded silt loam to sandy loam soil as raw material for Ellora plaster works. The locally derived soil seems to be selected with great care as poorly graded local soil was discarded. The unusual larger aggregates including gluconites, zeolites suggest the source of soil material almost certainly of basaltic origin. The earthen plaster is also characterized for deliberate addition of dolomitic lime to modify the properties of raw material and to enhance its binding properties. FTIR images show peaks for organic additives along with vegetal fibers found mixed in the plaster works. Petro-logical report shows insect activity in the mud mortar also confirmed through binocular microscopic observations. Due to coarser grain, the mud plaster is showing strong tendency to deform by grain breakage. The characterization has helped in the development of new materials for restoration having identical performance and compatibility as per original.