VR Experience
for Ajanta Caves

P3 REPORT

Sitara Shah
Guided by Prof. Jayesh Pillai
Co-Guided by Prof. Sumant Rao
Interaction Design
Industrial Design Center, IIT Bombay

Approval Sheet

The project titled 'VR Experience for Ajanta Caves' by Sitara Shah is approved for partial fulfillment of the requirement for the degree of 'Master of Design' in Interaction Design.

Guide:

Chair Person

Internal Examiner:

External Examiner:

Date: _____

Declaration

I declare that this written document represents my ideas in my own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/ source in my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

Sitara Shah
146330005
Industrial Design Centre,
Indian Institute of Technology, Bombay
April 1, 2016

Acknowledgments

I would like to thank Prof. Jayesh Pillai, my guide and Prof. Sumant Rao, my co-guide for their guidance and support throughout the tenure of the project. Thanks to Prof. Anirudha Joshi, Prof. Girish Dalvi and Prof. Ravi Poovaiah for their valuable inputs during the course of the project.

Special thanks to Rajesh Singh and the entire team of Prof. Sumant Rao for providing their research work on the Ajanta Caves.

Abstract

Virtual reality helps in seeing things that can only be imagined in real life. VR has been explored extensively in the field of education and has been used for experiencing many famous historical sites. This project attempts to design an immersive, interactive VR experience for one of the Ajanta Caves to let users interact with the caves from anywhere.

Ajanta is famous for its history, architecture, art, and scenic beauty. Thus it has a variety of tourists visiting each day. A well defined structure for its content distribution and interaction mapping has also been created to cater to diverse audience who want to access diverse and different information.

Key words: Virtual reality, Ajanta caves, Content mapping

Content

1. Introduction

The Ajanta Caves, also a heritage site, are 30 rock-cut Buddhist caves situated at a distance of 107 km from Aurangabad [1, p.13]. They are well known for their paintings based on the Jatakas tales, monolithic architecture, history and archeology.

These caves were excavated in horse-shoe shape from 2 BCE to 6 CE [2]. from basalt rock. Thus there has been a huge amount of deterioration since then. Preservation of this site is difficult with large amount of tourists visiting it each day. There are strict rules to reduce physical damage that restrict visitors from spending more than a few minutes in the caves. Flash photography and filming is strictly forbidden. This gives a visitor just a few minutes to spend within the cave.

The project goal is to create an immersive walk through in one of the caves (Cave 23) with the help of Virtual Reality (VR), which will allow the visitor to study and interact with it without physically being present at the location. It aims to design a structure for content distribution and its interactions, which can be followed to create immersive and interactive VR experiences for all the caves of Ajanta in future. The design process includes collection of all the information of the cave 23, mapping it to the appropriate interaction and creating a prototype with some of the mapped interactions.

Ajanta caves, being a rich historical and an architectural site needs to be known and appreciated by all. The VR experience is an attempt to reach out to maximum enthusiasts and replicate this experience for other caves.
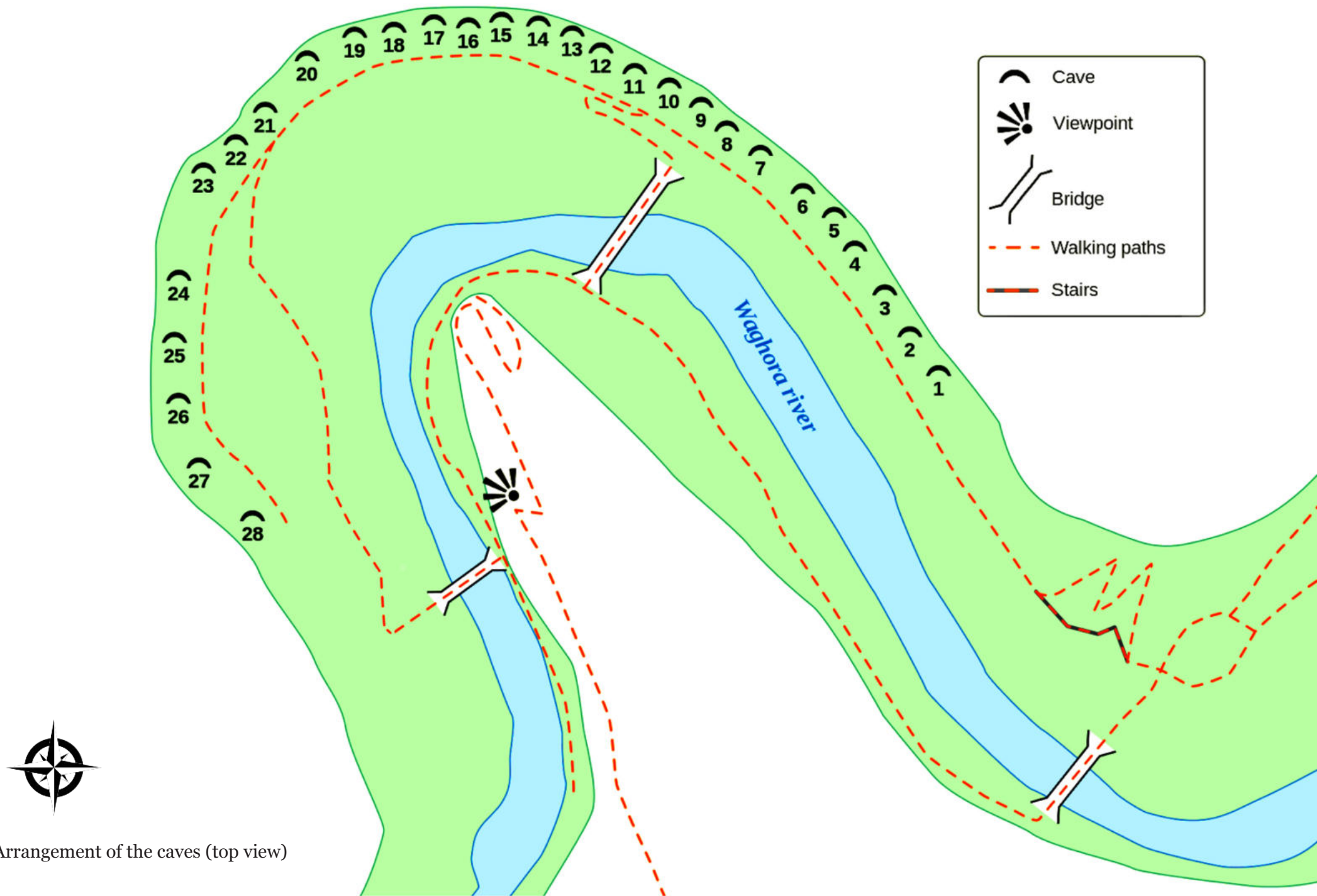
Fig. 1 Arrangement of the caves (top view)

2. Background Research

2.1 **Rediscovery**

The entire Deccan Plateau has Basalt rock formed by lava. Thousands of kilometers of these ghats are still untouched by humanity since irrigation, living or commuting is not possible here. Ajanta was discovered in 1819 by a British officer called John Smith while he had left for hunting on a horse near the site. He spotted a part of Cave number 10 where he later made his way and carved out his name on one of the pillars[2, p.3].

He is generally credited for discovering Ajanta. But there are multiple proofs of the knowledge of its existence way before.

2.2 **Ajanta before 1819**

The archivist from National Archives of Ireland, Matlafin Gill found newspaper clippings of the time before the 19th century which talked about the Ajanta caves. The local government records also show tax collectors collecting taxes from the people of Ajanta. ASI Director RC Agarwal also mentioned that Aurangzeb's sister maintained a diary that mentioned Ajanta during the reign of Aurangzeb when he shifted his capital from Dilli to Daulatabad. This manuscript is available in the National museum of India, although it has not been displayed for viewers.

2.3 **Arrangement & Timeline**

There are in total 30 caves in a horse shoe shape with each cave facing the Waghora River *(fig. 1)*. The 30th cave discovered is numbered 15A. Earlier, these caves used to be connected to the stream by a flight of steps.

According to Walter Spink's timeline *(fig. 2)*[3]Cave 9, 10, 12, 13 and 15A are believed to be the first caves dating back to 3 B.C.E. These were Viharas that were meant for the monks to stay. After 400 years, cave 26 was created which was the first 'Cave temple' (as mentioned in the inscriptions) of India after 600 years. This was a Chaitya Hall, a place where the monks prayed and lived.
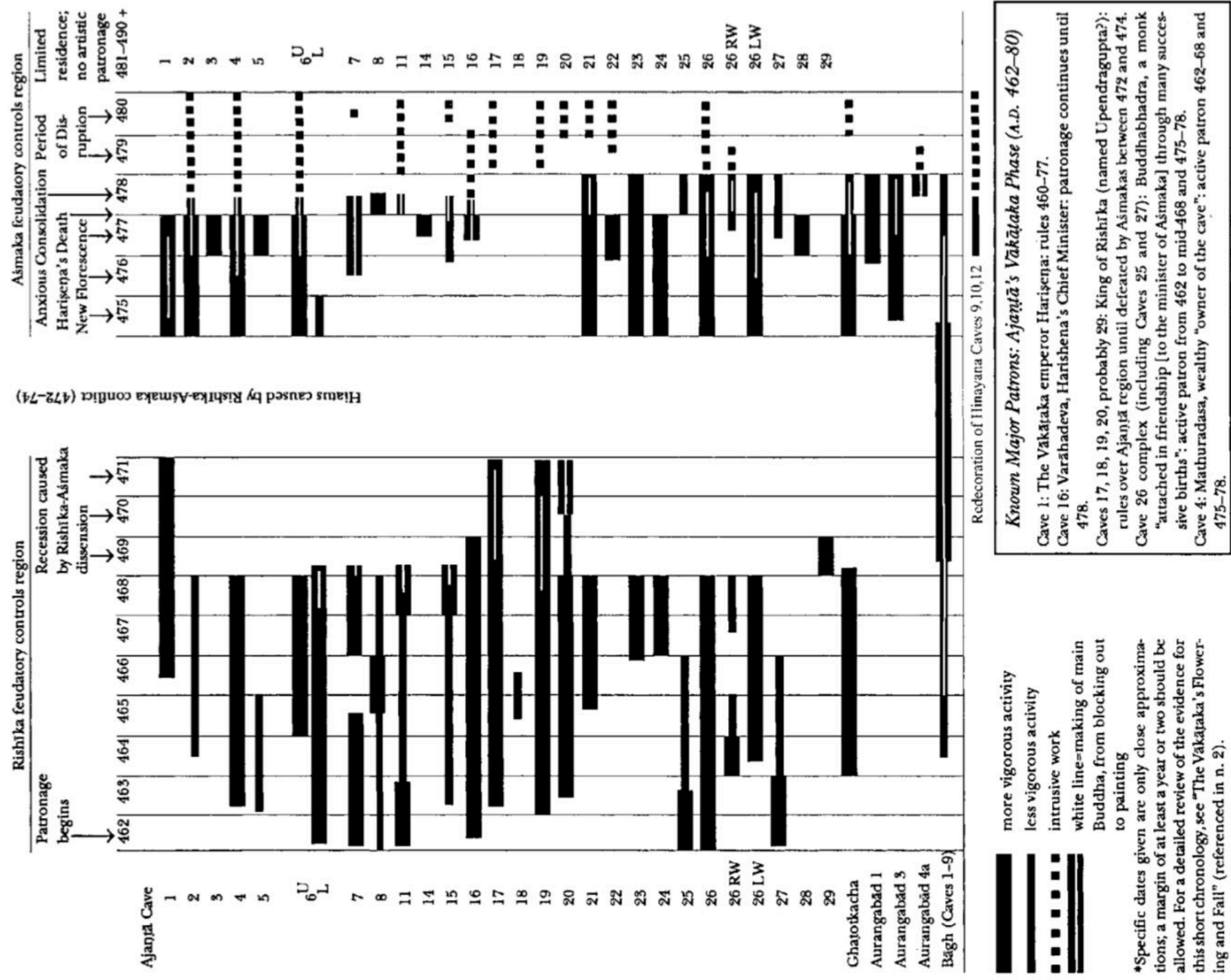
Rishīka feudatory controls region

Patronage begins

Recession caused by Rishīka-Asmaka dissension

Hiatus caused by Rishīka-Asmaka conflict (472–74)

Anxious Consolidation Hariṣeṇa's Death New Florescence

Asmaka feudatory controls region Period of Disruption

Limited residence; no artistic patronage

481–490 +

Ajaṇṭā Cave
1
2
3
4
5
6 U / L
7
8
11
14
15
16
17
18
19
20
21
22
23
24
25
26
26 RW
26 LW
27
28
29
Ghaṭotkacha
Aurangābād 1
Aurangābād 3
Aurangābād 4a
Bāgh (Caves 1–9)

Legend:

▬ more vigorous activity

▮ less vigorous activity

▪ ▪ ▪ intrusive work

white line=making of main Buddha, from blocking out to painting

Redecoration of Hīnayāna Caves 9,10,12 ▪ ▪ ▪ ▪

*Specific dates given are only close approximations; a margin of at least a year or two should be allowed. For a detailed review of the evidence for this short chronology, see "The Vākāṭaka's Flowering and Fall" (referenced in n. 2).

Known Major Patrons: Ajaṇṭā's Vākāṭaka Phase (A.D. 462–80)

Cave 1: The Vākāṭaka emperor Hariṣeṇa: rules 460–77.

Cave 16: Varāhadeva, Hariṣheṇa's Chief Minister: patronage continues until 478.

Caves 17, 18, 19, 20, probably 29: King of Rishīka (named Upendragupta?): rules over Ajaṇṭā region until defeated by Asmakas between 472 and 474.

Cave 26 complex (including Caves 25 and 27): Buddhabhadra, a monk "attached in friendship [to the minister of Asmaka] through many successive births": active patron from 462 to mid-468 and 475–78.

Cave 4: Mathuradasa, wealthy "owner of the cave": active patron 462–68 and 475–78.

fig. 2 Time Chart : Ajanta and Related Sites

2.4 **Paintings**

Ajanta has paintings that depict tales of the Jatakas and life of the Buddha. It expresses emotions like love, passion and tenderness unlike Ellora which also represents emotions like anger, jealousy and greed. The paintings reflect feminine characteristics in expressions & gestures of both men and women.

Robert Gill, a British officer and artist in 1846, was appointed by the Royal Asiatic Society was asked to make copies of these paintings (fig. 3). Unfortunately only four of his copies survived two consecutive fires. The copies are kept in the Victoria and Albert Museum in London and a number of his drawings are in the British Library.
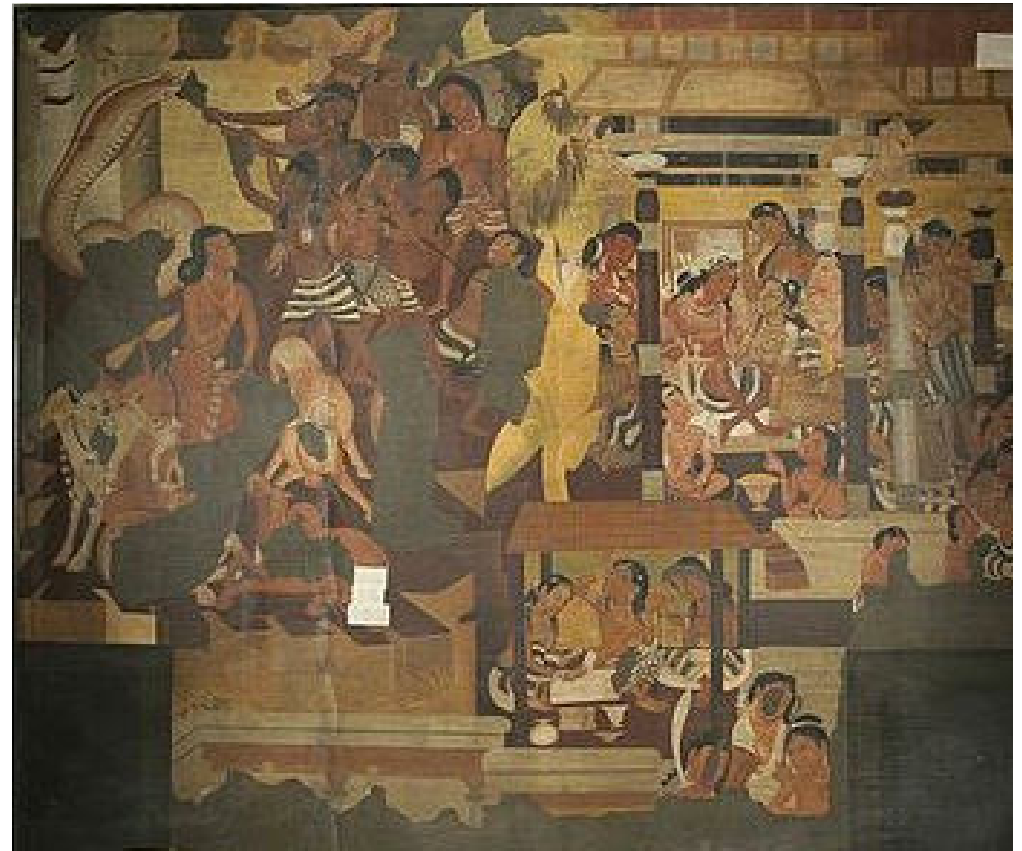

Fig. 3 Robert Gill's painting

3. Primary Work

3.1 **User Study I**

A questionnaire was created to understand the visitors of the site.

The interview was conducted with 5 art/ history lovers, 1 Architect, 1 History teacher, 1 photographer and 2 Designers. (All 5 have visited Ajanta)

Purpose of Question	Questions asked	Insight
Prior knowledge	- What do you know about Ajanta? - Have you read about Ajanta? - What medium did you use to get the information? - Do you knowabout the cave painting in Ajanta? - Do you know any Jatakas tales? Which one ?	- People mainly visit for picnics, educational trips - Ajanta and Ellora are very often confused - People visit first few caves and walk through others quickly - People do not notice the paintings at first - People are not aware of the Jataka tales - People want to know about life of Buddha - Parents spend more time in the caves with children - Architecture draws the most importance - Some people carry books to take notes - Some people do not trust the local guides
Purpose of visit Details of visit Experience Take away	- What was the purpose of your visit? - Whom did you go with? - Did you have a guide? - How many caves did you visit? - Which caves did you like the most? - According to you what is its importance? - Would you go there again?	

Problem Areas

On-site restrictions

- Flash photography, tripods & Video recording prohibited
- Visitors are not allowed to crowd at a point
- Visitors can spend only a few mins. inside the cave

Lack of Awareness

- About timelines of the cave
- About the paintings — leading to wrong interpretations
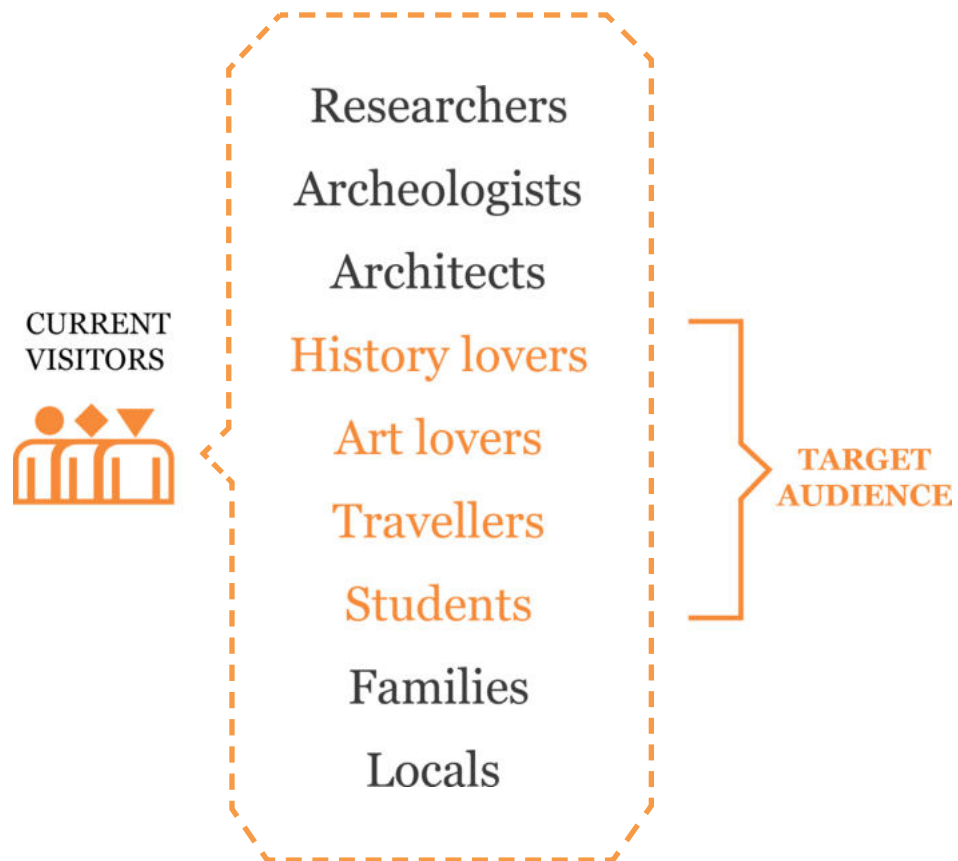- About the dynasties that originated during the time of Ajanta

Accessibility issues

- The old and weak cannot climb easily
- The palkhi service leaves people at the foot of cave 1
- Visitors often give up after a few caves

Lack of Network

- No phone network
- No 2G/ 3G data can be used

CURRENT
VISITORS

Researchers
Archeologists
Architects
History lovers
Art lovers
Travellers
Students
Families
Locals

TARGET
AUDIENCE

3.3 **Target Audience**

The project hopes to serve the users who are categorised as enthusiasts. Below are the people who currently visit the site and the highlighted is the target audience.

Enthusiasts:

- Are not experts
- Have basic knowledge about the places they want to visit
- Have a keen interest in exploring and learning
- Do not mind isolation
- Prefer small groups of fellow enthusiasts

3.4 User Study II

The second user study was held with three groups - 2 Experts, 7 Enthusiasts and 2 Gamers. Below are some questions asked along with the insights. (5/10 users have visited Ajanta)

Group	Questions asked	Insight

• **Expert**:
  Architect
  Archaeologist
	• How many times have they visited?
	• Why do they re-visit a site? For what?
	• What phones do they use?
	• Are they familiar with VR?
	• What would they expect from the virtual experience of the cave?
	• How would they like the information displayed?
		• Prefer no disturbance
		• Prefer going to the site
		• VR environment for reference and isolation
		• Have complete knowledge of the site
		• Not familiar with VR
		• Do not trust info till they examine on site
		• Take notes while studying the site
		• VR with detailed info and customisable settings

• **Enthusiasts**:
  Photographer
  History/ Art lover
  Bird watcher
  Traveler, Writer
  History teacher, Painter
		• Would revisit if they found site interesting
		• Have basic knowledge about the site
		• Would prefer guides or audio guides
		• Would like to re-visit alone or in small group
		• A bit familiar with VR
		• Expect diverse information, more visual
		• Should be accessible from anywhere

• 2 Gamers	• Have they played a VR game? • Understanding of interactions and transitions • Understanding visual distribution of data	• Interactions must be indicative from far • It should be easy for users to avoid active interactions as and when they like • Should be able to switch 'scenes' easily • Should not feel uncomfortable with environment

3.5 **Project Goals**

Create an immersive, interactive, virtual environment for one of the caves of Ajanta.

Introduce it to a diverse group of Enthusiasts who can access it from anywhere without being physically present at the site.

Design an interaction and content distribution structure that can be implemented on other caves to showcase global (overall) as well as cave specific information.

4. Case Study

4.1 Similar Work

London's Natural History Museum

David Attenborough's VR experience lets visitors explore the ocean floor as it existed 550 million years ago during the Cambrian period, when no life existed on Earth expect water *(fig 4)*. The 3D journey also lets one see some of Earth's earliest inhabitants and the Great Barrier reef. [Watch it here : https://youtu.be/KH2YzotvLiw]

The Mona Lisa room and Digital Mona Lisa

The Mona Lisa room lets one get private access to view the most famous paintings in history all together with the help of VR. [Watch it here : https://youtu.be/ZZXQpBfNgV4]

The digital Mona Lisa, in France, uses motion sensors to detect when a viewer is looking at it, allowing it to react. [Watch it here : http://www.dailymail.co.uk/sciencetech/article-3159292]

3D Dunhuang caves

A 360-degree VE has been designed for the Dunhuang Caves. These caves are 1500-yr old painted Buddhist cave from northwest China. *(fig. 5)*. [Watch it here : https://youtu.be/BbU7LvPhLSE]

Dali and Disney museum

Dali and Disney museum has created a VR experience where the viewers feel like they are inside a painting *(fig. 6)*. Visuals from Dalí's works like elephants, birds, ants etc appear before their eyes. [Watch it here : https://youtu.be/o8L2_8TdINA]

AR for Rome's Coliseum

AR for Rome's Coliseum rebuilds the missing sections in 3D and shows the viewers how it originally looked *(fig 7)*. [Watch it here: https://youtu.be/WOVjISxlhpU]

Fig. 4 London's Natural History Museum (source: Nhm.ac.uk, 2016)

Fig. 5 Digital 3D Dunhuang Caves exhibit at the Hong Kong Book Fair (2016)

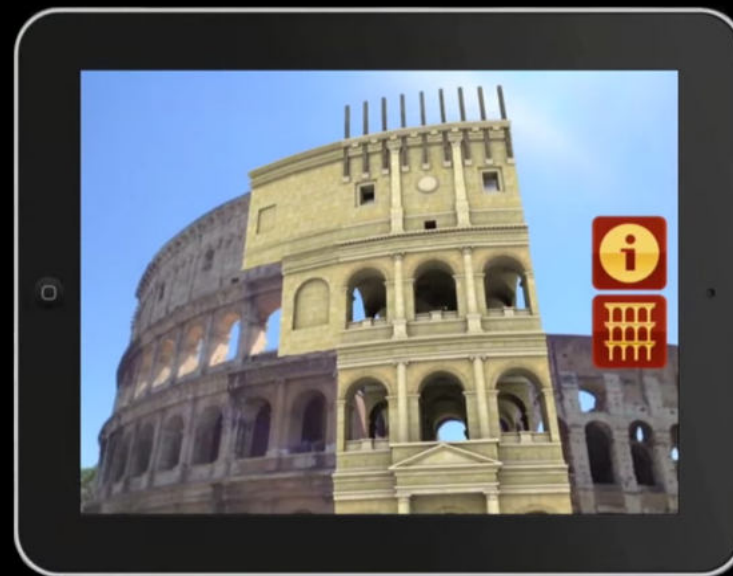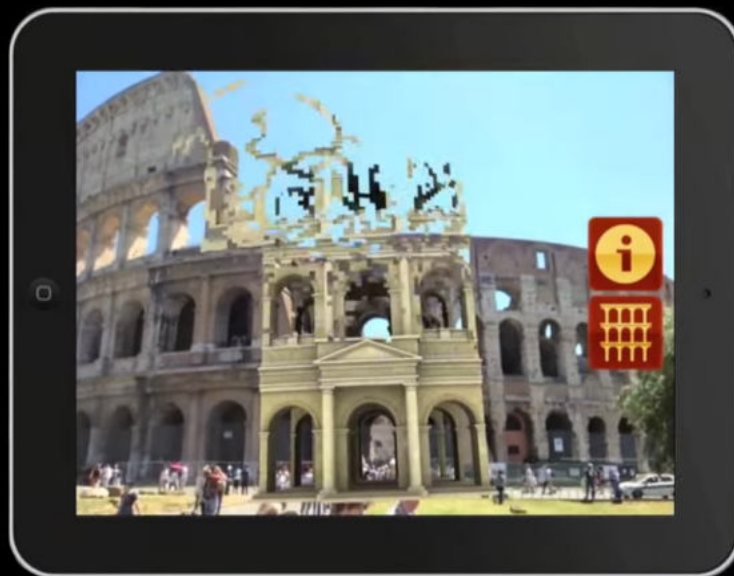Fig. 6 Dali and Disney museum (source: B.fastcompany.net, 2016)

Fig. 7 AR for Rome's Coliseum (source: Mona Lisa Room Virtual Reality - Unreal Engine Demo & Oculus Rift, 2016)

4.2 **Current Technologies**

a) Virtual Reality and Immersion

Virtual reality is an artificial, immersive system that lets the user replace the real environment and interact with it. Augmented reality is integration of digital information with real environment.

The VR can be fully or partially immersive. The experience of the user is dependent upon the immersion of VR. A partial immersion gives a feeling of 'looking at' a virtual environment (VE). Where as full immersion supports the feeling of 'being in' the VE. *(fig. 8)* [4]

The immersion is measured from field of view (fov) ie: the amount of users view that can be covered. The type of display chosen for VR denotes the fov. *(fig 9)* [4]
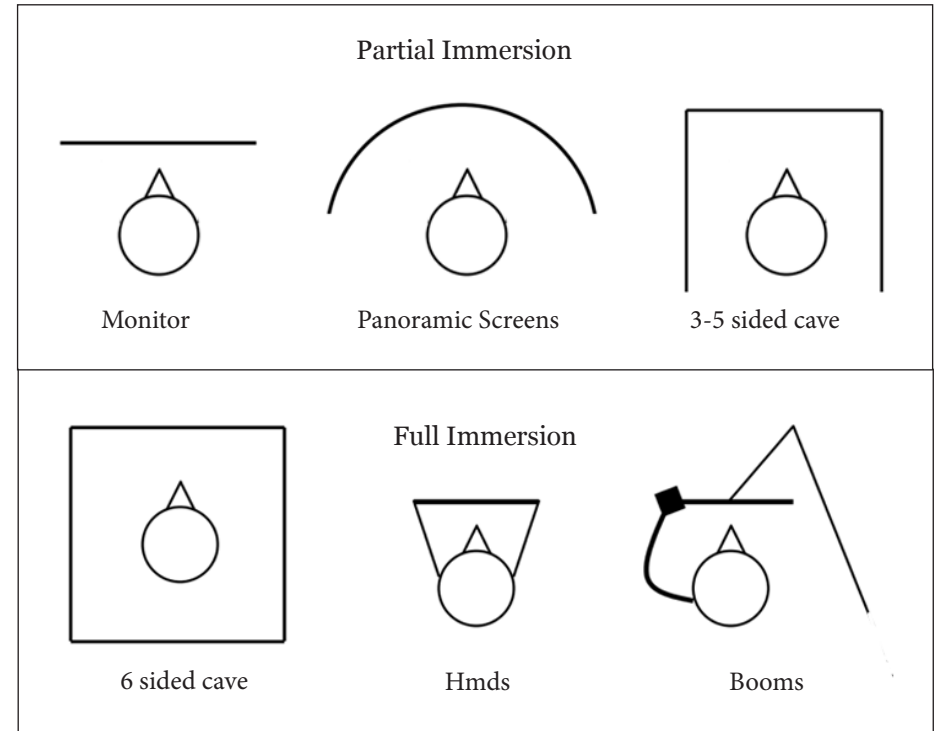

Fig. 8 Full & partial immersion

Display type	Field of view (approx)
Computer monitors	20-40°
Hmds/booms	30-80°
Holobenches	80-120°
Large wall-mounted displays	100-140°
Panoramic displays	160-180°
Caves	upto 360°

Fig. 9 Field of view of various displays

b) Interactions in VR

Orientating

Orientating in VR lets one look around in the VE. For immersive displays it works fine since the field of vision of user is more. The problem arises when partial immersive displays are used since the displays do not completely surround the user. This can be solved by rotating the VE while the user remains immobile. Devices like hand-held joysticks or trackballs to tracking the orientation of the user's head can be used to rotate the VE [5].

Moving

Moving in VR lets one move around in the VE. This is normally supported by letting the user move in the physical space while tracking his position to place him in the VE. But many times when the VE is larger than the real space, alternative solutions are necessary that enable the user move in it without actually moving. A common approach to solve it is by letting the user move the virtual world while remaining still. This can be supported by external devices or other techniques [5].

Acting

Tasks of selection/picking, moving, rotating and transforming objects in the VE and controlling levels in the system designed are all covered by Acting. It is normally supported by implementing a virtual hand or pointer techniques. It can be done also by gesture recognition using data-gloves or motion tracking [5].
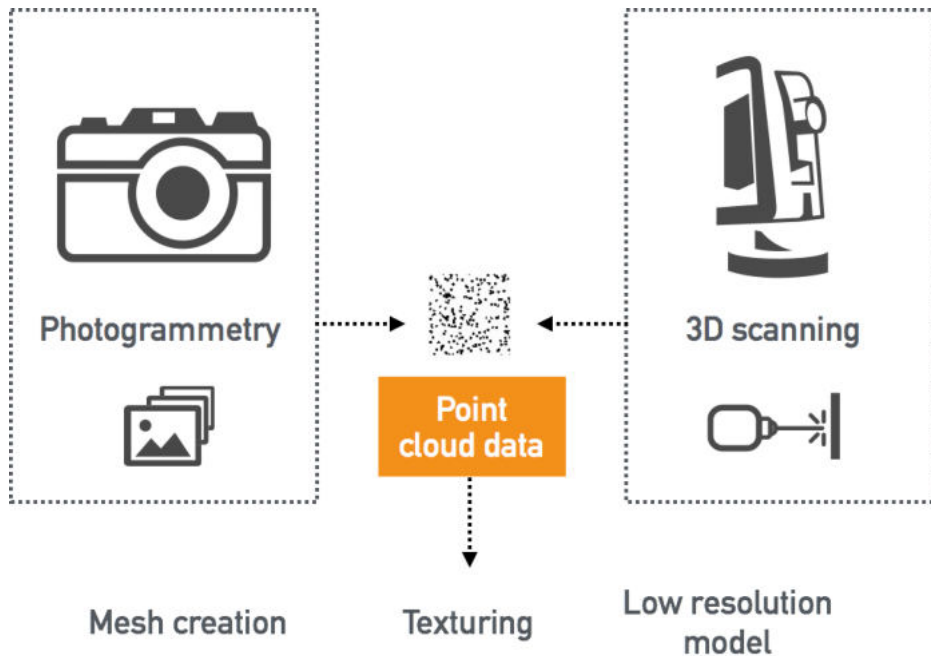
Fig.10 Photogrammetry and 3D Scanning to get point cloud data

c) 3D Modeling with Photogrammetery & 3D Scanning

To create a VR walk through for a cave, the 3D Model of the cave is re-quired. This can be created by either Photogrammetry or 3D scanning which generates point cloud data. This information is used for the creation of mesh and low resolution 3d model that can run on tablets and phones. *(fig. 10)*

Photogrammetry is the science of making measurements from pho-tographs. For this purpose, multiple photographs of an object/ envi-ronment are taken and stitched. The output of which is a 3D model of some real-world object or scene.

3D Scanning is done with a 3D scanner that analyses a real-world object or environment and collects its information in points *(fig. 11)*. This is done with laser beams. This information can then be used to construct digital 3D models *(fig. 12)*.

Fig. 11   Cloud point data from 3D Scanning

Fig. 12   Creation of a mesh for 3D Modeling

5. Design Opportunities

5.1 Interaction with AR

A book giving information about Ajanta and cave details by augmented data to study the different aspects of the caves *(fig. 13)*. Augmented reality (AR) can also be used on site to display parts of cave that are no longer in shape. For eg. *(fig. 14)* Cave 26 had a main entrance and a chamber that has left its mark and no longer stands. This can be shown to visitors through AR with the presence of a tablet or phone.

5.2 Cave Timeline

Timeline of caves *(fig. 2)*[3] as and when they were created have been often debated upon by researchers. An interactive timeline to represent the data of how the 30 caves were created along with display of information about the era. Other information like cave innovation, donors, periods they belong to, types of cave etc can be integrated with the interactive timeline.

5.3 Cave specific Immersive VR

The team currently working on Ajanta has created a window VR for cave 1 that focuses on its paintings. Making this experience immersive and creating a walk through for it can let a user have a better experience. The same can be then implemented on other caves by designing a structured template for content and interactions.

5.4 Making of a cave

Multiple caves were built simultaneously at a time. Due to this there were multiple influences in element from one cave to another. The study of what parts of the caves were made first help in understanding the architecture, loopholes, and influences on one another *(fig. 15)*. The ground plan of cave 26 shows the order of the chambers as they were made. Cave 25 was made above the right side of cave 26, before parts 3B and 3A, which restricts cave 26 from having a cell below it due to insufficient space for minimum height. Thus the cell was planned near the main entrance (Ruined structure).

Fig.13   Augmented book

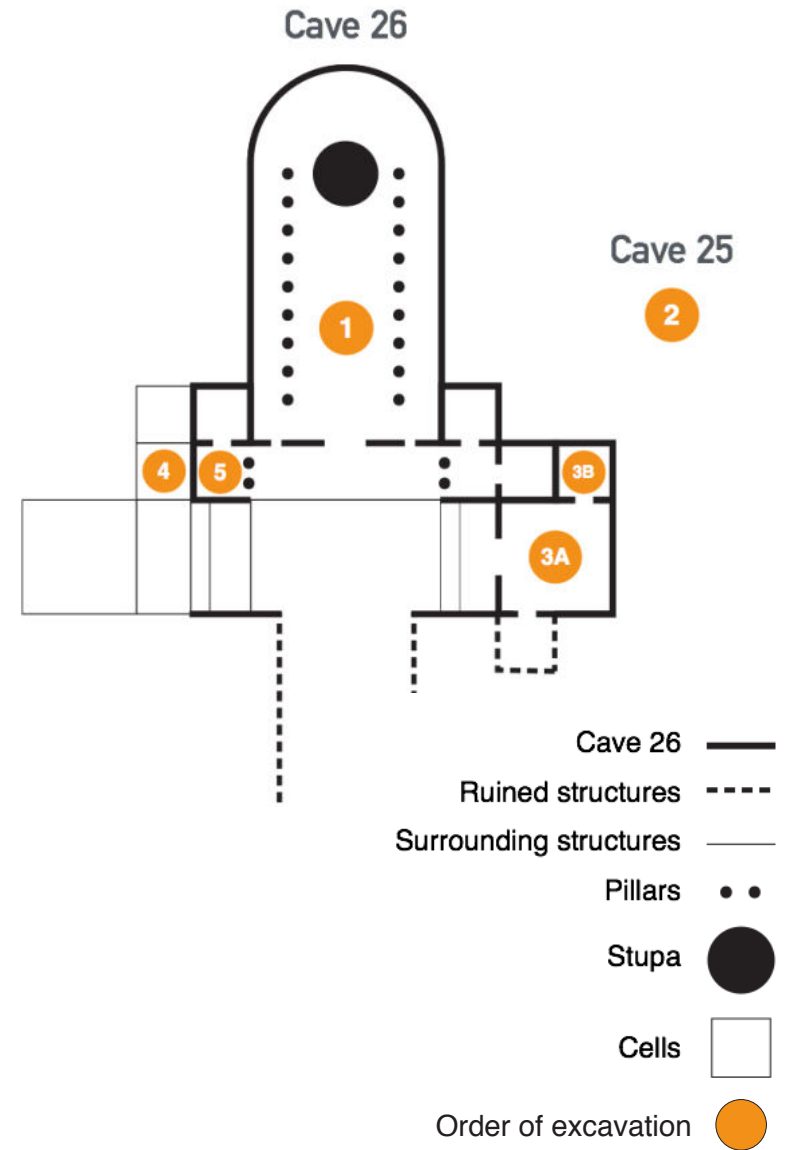Fig.14   Cave 26 with the missing entrance augmented

Fig. 15 Cave 26 ground plan

6. Resources

To create a model of the cave, the following information is needed:
- Point cloud data to generate a model
- Photographs of the exterior and interior for texturing and patching on the model
- With the help of above two, a low resolution model is then created with mesh and textures.

The 3D Scanning was only permitted for caves without paintings to avoid damaging the frescoes. Thus only cave 21-26 were scanned where cave 26 is not scanned completely. Only cave 23 and cave 26 have been entirely photographed for texturing information.

Thus the cave chosen for this project is Cave 23.

7. Focus

Due to lack of resources, a prototype is made focusing on cave 23. The structure of information showcased is designed in a way such that it can be later implemented on other caves as an when the 3D Models for them are created.

The prototype for Cave 23 will represent cave specific information along with global information that applies to all Caves. This includes type and period it belongs to, stories/ facts of the cave along with its architecture and history of Ajanta.

8. Experience Design

The process is divided into multiple steps as follows:

- Exploration of Content
- Information Architecture
- Interactions (with respect to content, navigation and transitions)
- Creation of Assets

8.1 Exploration of Content

To provide information about the cave, relevant content was gathered from verified sources like Walter Spink's 6 Volumes of books on the caves of Ajanta.

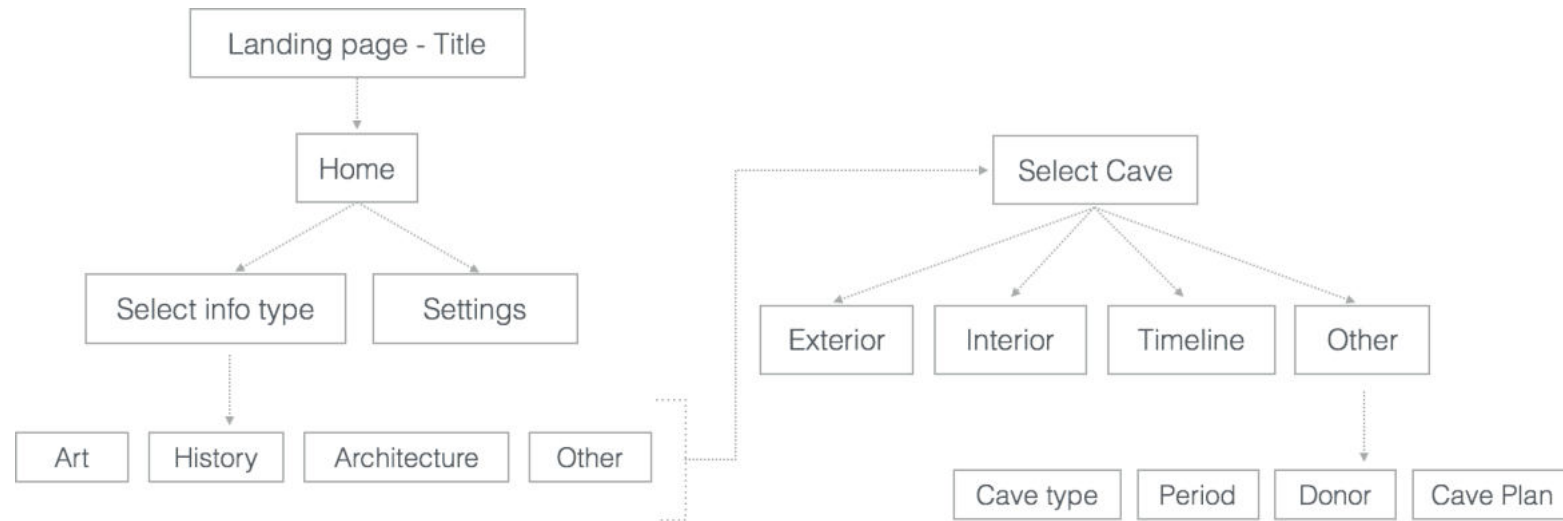## 8.2 Information Architecture

Expanded Approach

This approach lets a user choose the information he would like to see. Thus the background of the user plays an important role. Since this platform targets enthusiasts, the options for the user to pick would be:

Art, History, Architecture, Other. Picking of category would not restrict or filter the information but it would prioritize content and represent it in different way. The next step is the selection of a cave that would take the user to the doorstep of the desired cave. Information regarding the interior/ exterior, its timeline, and other cave specific details is then showcased *(fig. 16)*.

Project Approach

The expanded approach requires complete knowledge of Ajanta as a whole along with details of all 30 caves to understand the distribution of content for the user type. Since the project timelines do not allow me to research in that depth, the project approach would be focusing on showcasing various type of information about one cave only. Thus the step of letting the user choose the type of information has been avoided. The user can start exploring by selecting the cave directly *(fig. 16)*.

Expanded Approach

- Landing page - Title
  - Home
    - Select info type
      - Art
      - History
      - Architecture
      - Other
    - Settings
  - Select Cave
    - Exterior
    - Interior
    - Timeline
    - Other
      - Cave type
      - Period
      - Donor
      - Cave Plan

Project Approach

- Landing page - Title
  - Home
    - Timeline
    - Caves 1-29
    - Settings
  - Select Cave
    - Exterior
    - Interior
    - Timeline
    - Other
      - Cave type
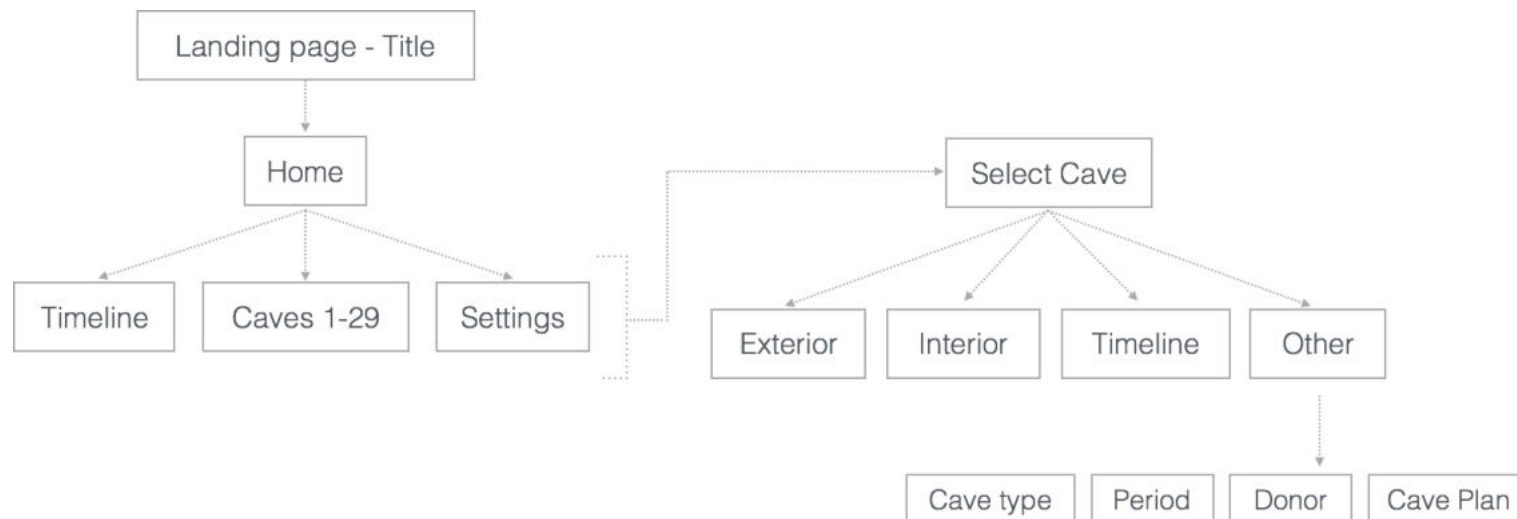   - Period
      - Donor
      - Cave Plan

Fig.16 Information Architecture

8. Experience Design

8.3 Interactions

The interaction is divided into 3 types with respect to:

a) Content Mapping

The information is distributed into 'Global Categories' that is mapped to the interactions (view Appendix A). This method makes it simpler to choose the appropriate assets to create interactions. This forms the grammar for content distribution that can be followed for all the caves.

b) Navigation in the Virtual Environment

The navigation within the VE can be done either by physically moving or remaining still. Since the platform created can be used in any real space, there is no guarantee of enough space available for the user to physically move in. Thus the navigation chosen for this VR project allows the user to move the Virtual world towards or away from him/ her without locomotion. The movement can be done with the use of a clicker/ button on a head mounted device. In this case, I have chosen Google Cardboard (or Cardboard inspired head mounted devices) since it's extremely affordable for masses.

c) Transitions

In an immersive VR it's important to keep the user at ease. VR sickness is very common and leaves many users dizzy. Transition from one interaction to another, change of environments within VE and speed in which a person moves in the VE are some elements kept in mind.

All the interactions mapped for the cave have three states - Far, close and click-able to assure the user of the response expected. Interactions abruptly starting and ending have been avoided.

Since all the actions like navigation within the cave, navigation across the platform (eg - from home to settings) and interacting with elements of cave are taken care with single clicks on the Cardboard, the transitions along with content need to follow a grammar too.

8.4 Creation of Assets

The interactions designed for different content require assets like text, images, animation, audio etc. These assets are then created or collected from reliable sources. (Books by - Walter Spink's and Rajesh Singh)

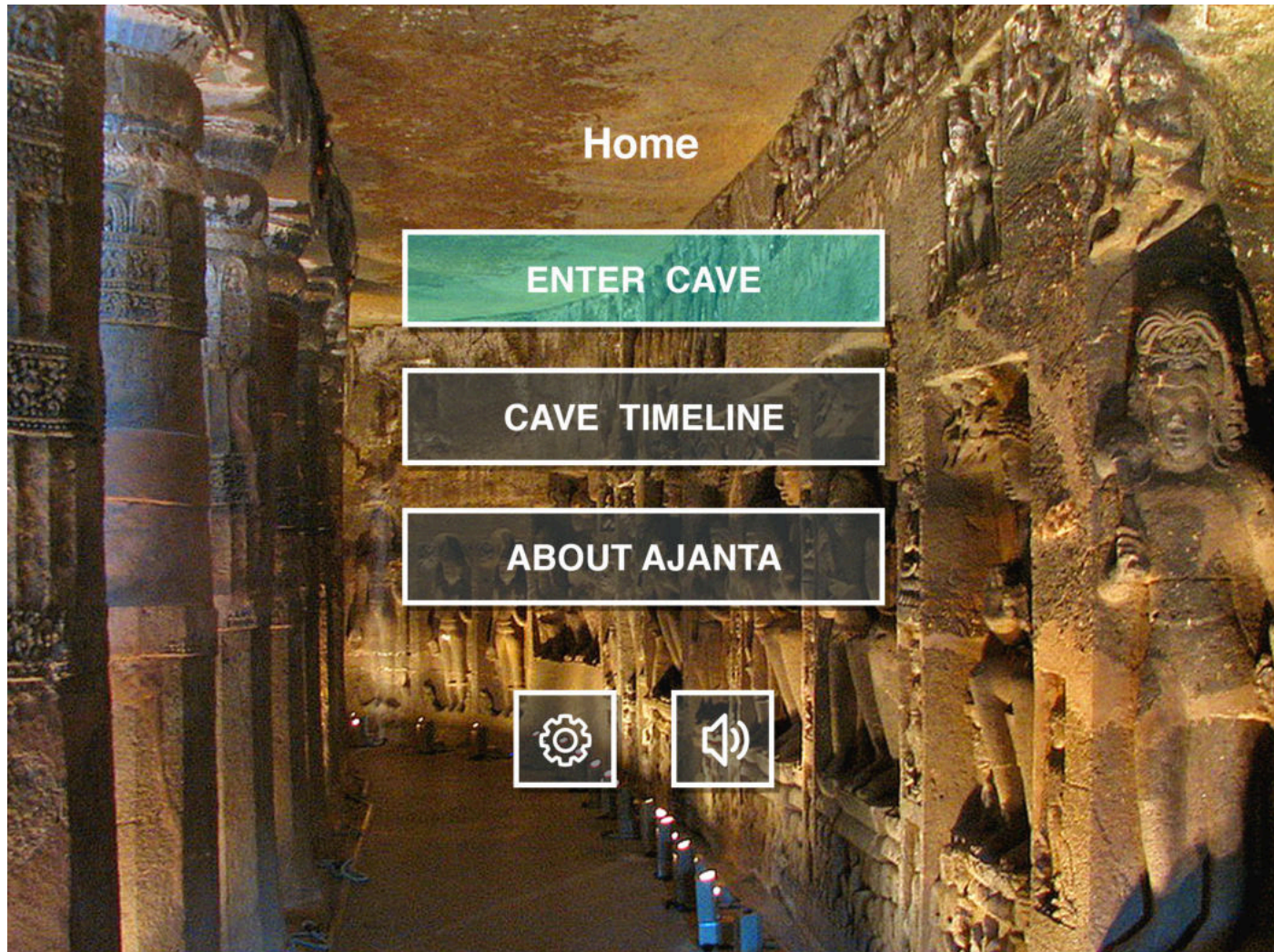# 9. Interface Design

The screens from a head mounted device (HDM) :

Fig. 17 Landing screen
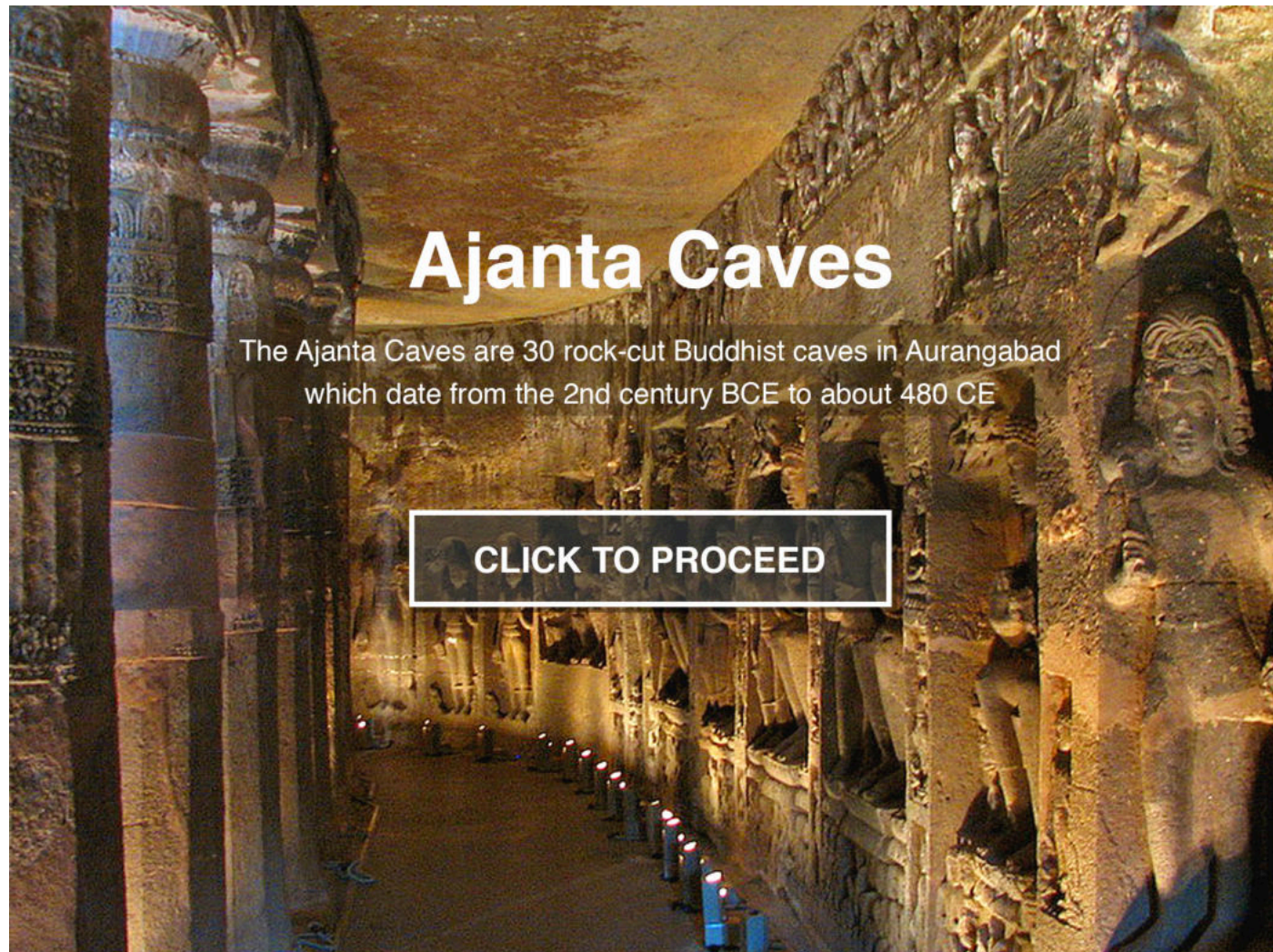
Landing screen

The 'Click' refers to the magnetic click on the HMDs (Google Cardboard in this case)

All the actions in the flow of this journey are designed in a way that can be done with a single click (*fig. 17*).
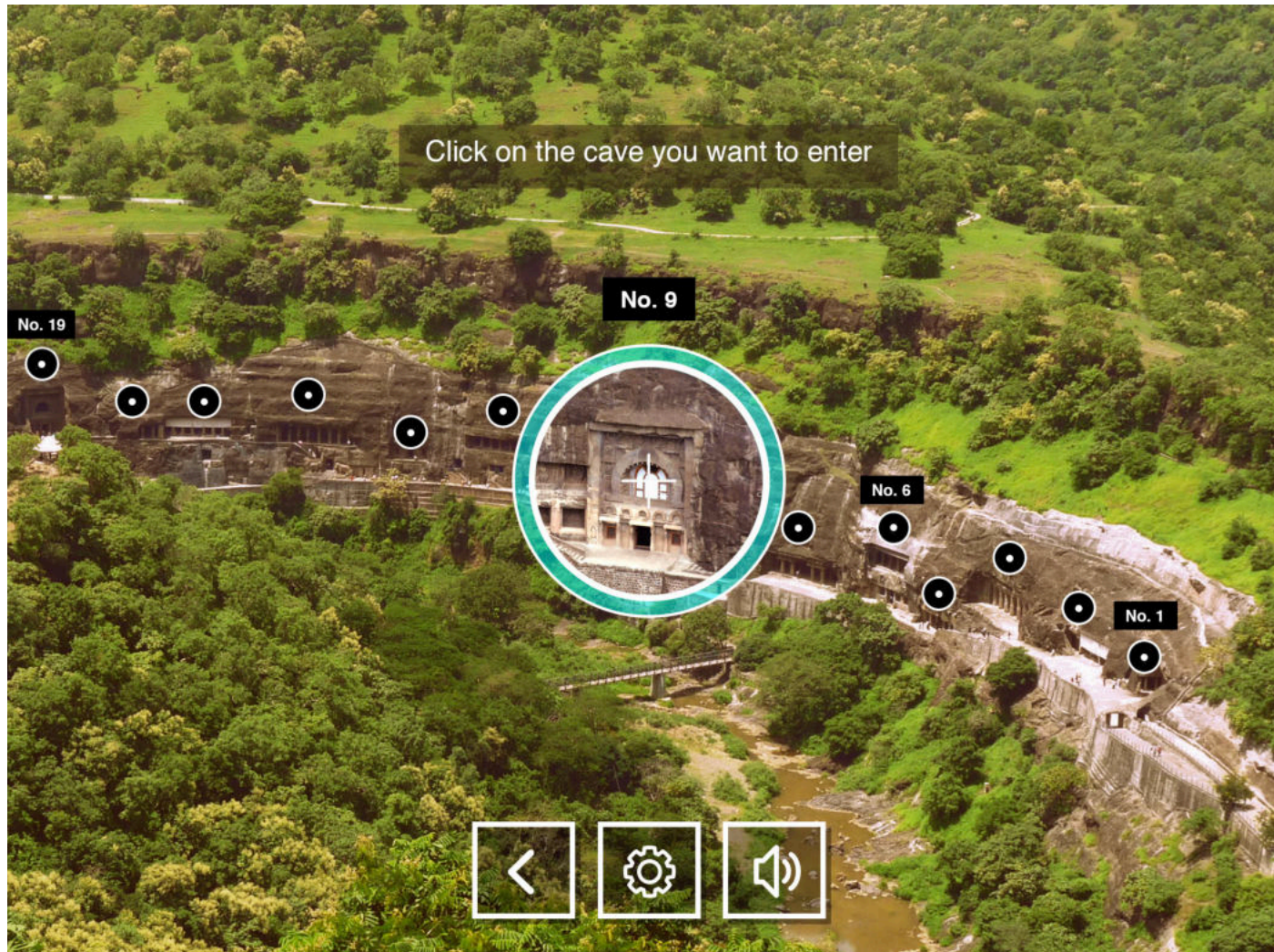
Fig. 18 Home screen

Home Screen

This platform lets you see the overall timeline of all the caves in Ajanta, Details of a specific cave chosen out of 30 and basic information about Ajanta *(fig. 18)..*
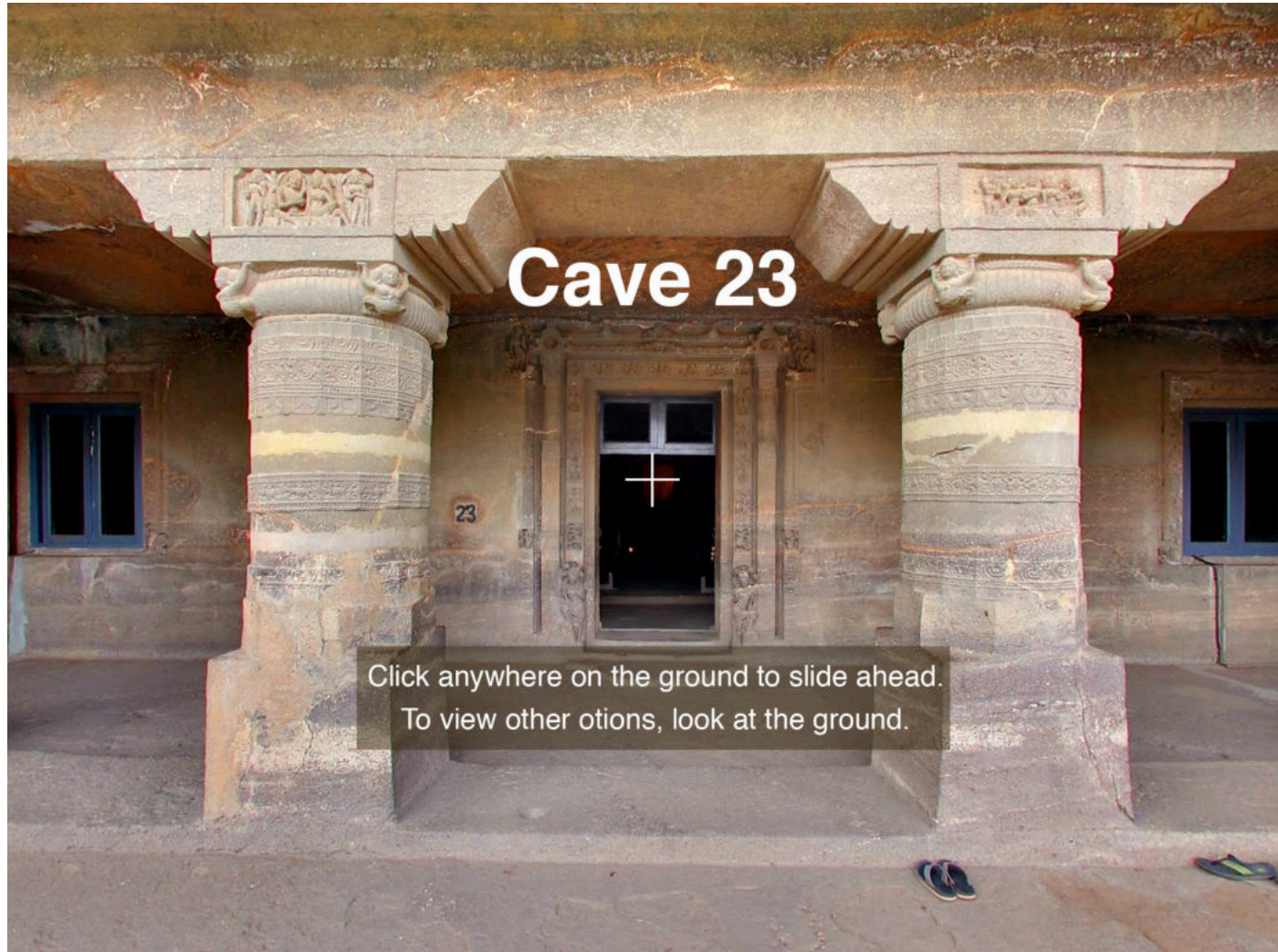
Fig. 19   Select Cave

Select Cave

The screen shows a panoramic view of all the caves of Ajanta taken from the Viewpoint *(fig. 1)*.

The user can scan through the caves, have a better look at it as they zoom in on hover, and click to enter it *(fig. 19)*.

Entering a cave

The user can explore the cave by navigating. Navigation can be done either by physically walking in an empty real space, using a joystick or by clicking on the ground to slide to a point *(fig. 20)*.

Fig. 20 Cave entrance

Fig. 21 Menu options at the foot of the character
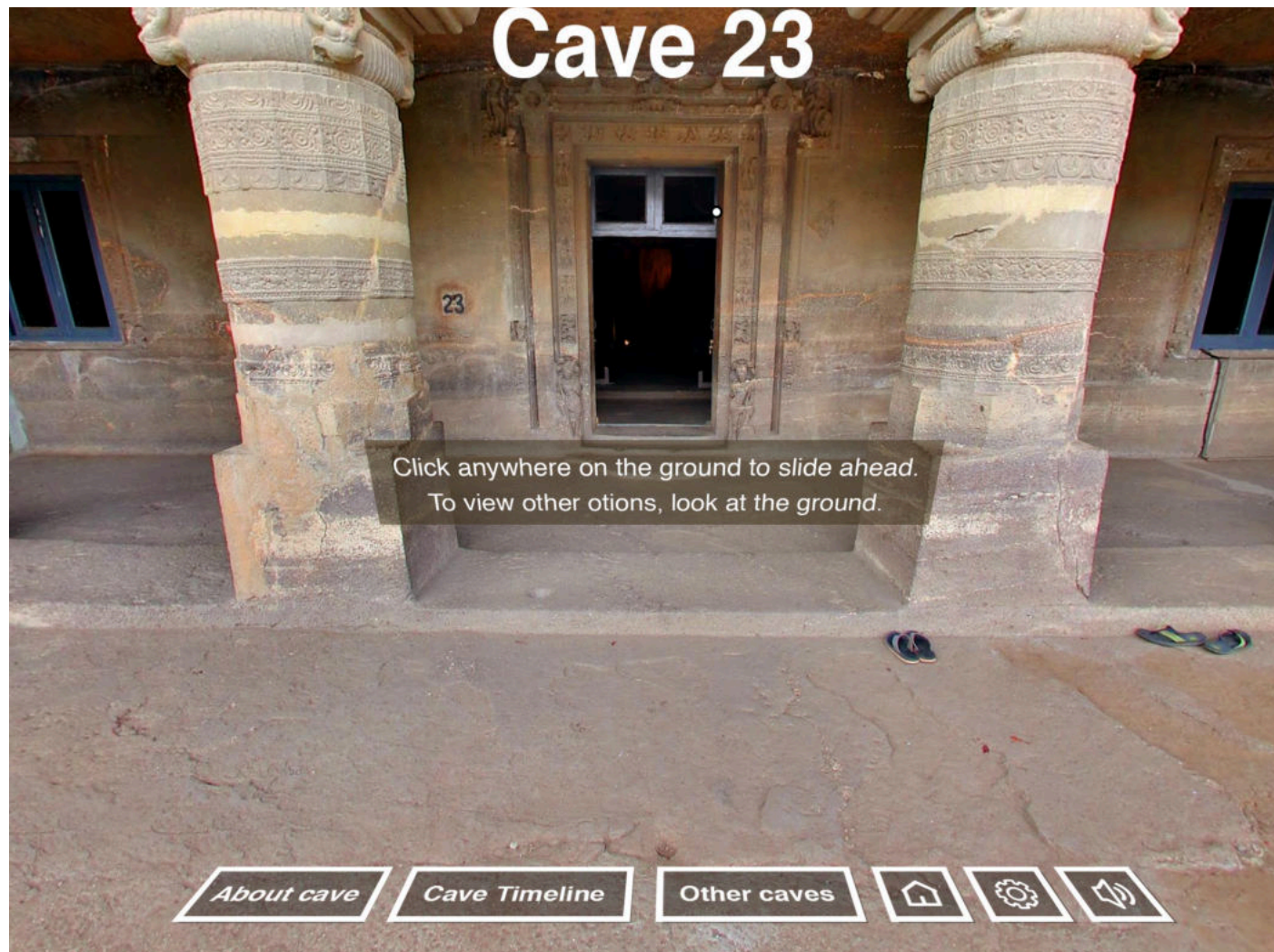
Entering a cave

Other options like cave selection, more information about the cave and its timeline can be accessed by looking torwards the feet of the charater in the virtual environment *(fig. 21)*.

Fig. 22 Cave interactions

Cave interactions

The interacting points inside the cave have 3 modes: far, close and clickabe.

'Far' off mode is meant to indiate the users about the interacting points even if they are not near them. This prevents missing out on information.

'Close' mode indiactes that the interaction can be played.

'Clickable' mode is nothing but hovering over the 'Close-by' elements *(fig. 22)*.

Fig. 23 Cave interactions
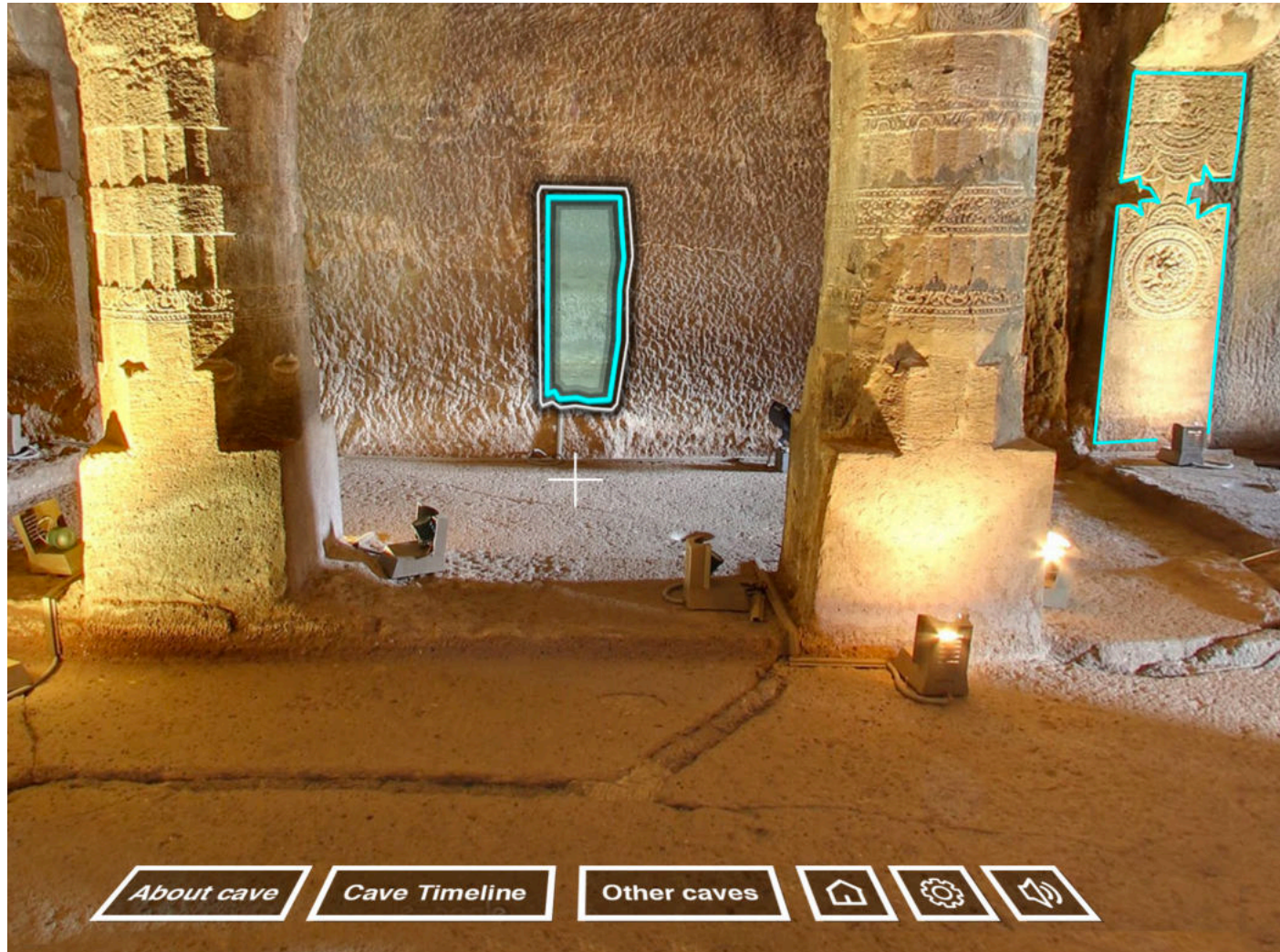
Cave interactions

The 'cave timeline' and 'about cave' can be accessed from anywhere once the user has selected his cave to enter. These interactions are not marked at particular points *(fig. 23)*.

Fig. 24 Cave interactions

Cave interactions

The content displayed on playing the interactions are in the form of Images, text, audio and animation *(fig 24).*

The audio can be muted by clicking on the speaker option at the characters feet. *(fig. 23)*

Layout and Timeline

The 30 rock-cut Buddhist caves of Ajanta lie 107 km from Aurangabad in a horse-shoe shape. They were excavated between 3 BCE to 6 CE from Basalt rock. Each cave was connected to the stream by a flight of steps.

Fig. 25 Cave Timeline

Cave Layout & Timeline

The timeline that was created by Walter Spink *(fig 2)* was a vertical one that displayed the caves in the ascending order by the nuber they are given. However, the layout of the caves is not in the same order.

The timeline that is re-designed in this project is based on the the layout for better understanding of how the caves were excavated. *(fig. 25, 26)*
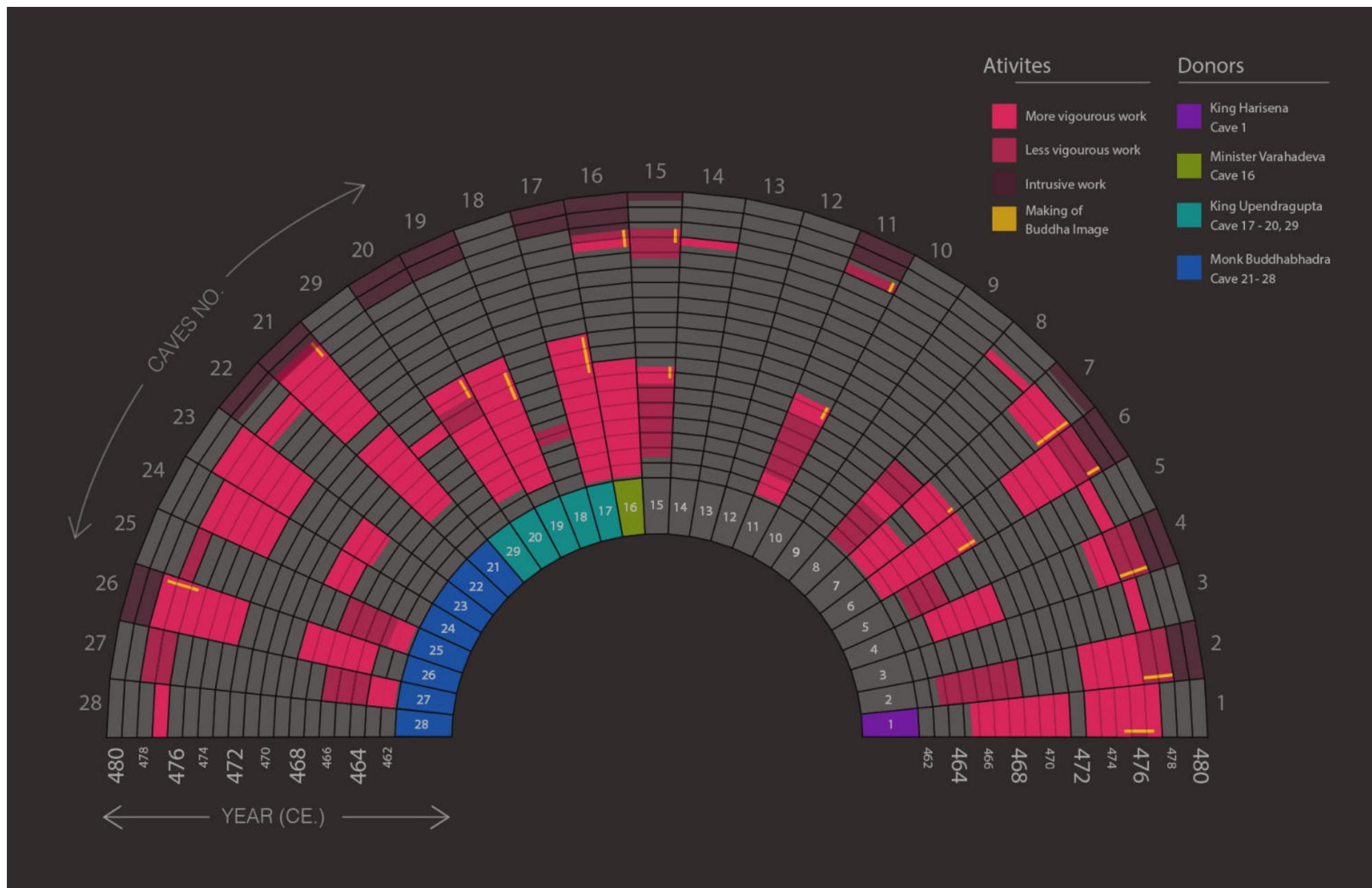
Fig. 26 Cave Timeline

10. Prototype

The video prototype that is designed showcases the entire flow from the landing screen to the cave interactions. The functional prototype that requires a Google Cardboard, earphones and an Android phone, represents the basic interactions within the cave 23 and the overall timeline of the caves (view Appendix B).

11. Scope

The project covers cave no. 23 's interior and the porch. The information displayed will be in the form of Audio, Text and Animation. A structure has been designed to distribute content and map specific interactions across any cave of Ajanta. This template can also be referred while working on other historical sites.

Some of the assets used for the purpose of the prototype are in the form of audio, text and visuals (most of them being visuals or animations). More intricate form of 3D elements are recommended as assets for the content related to evolution of elemets – pillar, doors windows etc. The structure of the platform and the mapping of content with interations allow easy replacement of one asset by another at a later stage.

The functional protoype gives a glimpe of some of the content shortlisted out of all the information gathered about Cave 23 (view Appendix A).

12. Evaluation Plan

Heuristic Evaluation will be conducted with 4 to 5 users to understand how comfortable they are with navigating across the platform and get their views on how appropriate are medium of interactions used.

Since the user has complete control of his/ her movement, the ease at which they navigate, explore and interact will be evaluated.

Think-a-loud test will be conducted with 4 to 5 Enthusiasts and at least 3 experts to evauate the distribution of content & its categorization and the information architecture of the platform.

13. Evaluation

Contextual Inquiry with 4 users Heuristic Evaluation with 3 Experts was conducted. A semi-structured interview was conducted to find out the following things:
- How comfortable are they in the virtual environment?
- How do they feel about the isolation?
- Are they able to locate and reach the interaction?
- How is the readability and visibility?
- Is the method of presenting information sufficient?
- How else would they like the interactions apart from the current?
- Why would they use the platform?

Insights

- It is a recreational platform. User would use this platform to explore more than learn. It is thus, not a platform for experts to refer.
- Micro interactions should be used subtly to guide the user to information. Since the VE is explored without physical movements, the user must not miss out on information at various parts of the cave.
- Information displayed at any point should face the user in the virtual environment and must have minimal usage of text.
- Accurate outlining of elements instead of rectangular boxes will make it more interesting.
- Interactions get intrusive when the model of the cave is not well lit up. Thus the VE must be bright enough to see details of the inside.
- The interactions should be indicative only when user is in a certain radius else the triggers(highlighting) gets in the way of exploring.
- If there is a hurdle between the navigation path, the user should make his way without colliding.
- Most caves are mostly symmetrical with plenty of pillars. Markers need to be there to avoid users from revisiting the same sections.
- Gaze duration can be used to show desired information.
- Timeline should be an interactive one which is linked to other caves and their information.

14. Future

The cave prototype made for one cave can be easily created for others by following the Content mapping process. The content collected can be reviewed by experts and mapped to interactions. The project will expand to different types of users who can customise the information flow according to their desire. This allows a diverse type of users to gain desired information about Ajanta.

The back-end for the system will allow the admin to easily populate the database with the help of defined mapping process of different type of content. Thus this process of distribution of content can be used for any important site to create a VE for it.

15. Conclusion

The goal of creating an immersive, interactive, VE for one of the caves of Ajanta for enthusiasts to access from any place was partially fullfiled by showcasing it in the form of a video prototype and a functional one with sample interactions.

While understanding the requirements of the user, the project gave rise to the process of Content distribution and interaction mapping that was earlier not a part of the scope. The method of using such a model can help not only creating VR for the other caves but also helps in creating experience for any other important historical or Archaeological site.

The process of Content mapping not only helped me in mapping content to appropriate interactions but also helped me to create a well defined method for picking the right form of assets for each type of categories. Thus the process of distributing content and choosing its representation became far more easier.

Using VR for educational purpose can help in creating new levels of engagement for the users. Retention of the information is stronger because of the ability to represent information that can not be imagined in a real space.

16. References

1. Singh, R. K. 2016. *An Introduction to the Ajanta Caves*. Vadodara : Hari Sena Press Private Limited

2. Spink, W.M. 2007. *Ajanta: History and Development, Vol 5 Cave by Cave*. Boston:Brill

3. Spink, W.M. 2009. *Ajanta: History and Development, Vol 4 Painting, Sculptre, Architecture Year by Year,* Boston:Brill

4. Kjeldskov, J. (2001). Combining Interaction Techniques and Display Types for Virtual Reality. In Proceedings of OzCHI 2001: Annual Conference of the Australian Computer-Human Interaction Special Interest Group.

5. Kjeldskov, J.K.. 2001. *Interaction: Full and partial Immersive Virtual Reality Displays*. Bergen: University of Bergen

6. Spink, W.M. 2014. *Ajanta: History and Development, Vol 6 Defining Features*. Boston:Brill

16. Appendix [A]

Content Mapping

16. Appendix [B]

GENERAL PLAN
OF THE CAVES OF
AJANTA

Cave 1
Emperor Harisena
466-71; 475-77

Cave 4
Mathura
463-468; 475-478

Cave 16
Minister Varahadeva
462-469; 477-478

Caves 21-28
Controlled by
Monk Buddhabhadra
with Dharmadatta
and Bhadrabhandhu
463-68; 475-478

Caves 17, 19, 20, 29
Upendragupta, King of Rishika
463-471

Scale of 100   0   100   200   300   400   500   600   700   800   900   1000 feet

J. Burgess.

Wⁿ Griggs, Photo-lith.

The dates show the outer limits of each individual's patronage.
Some vary slightly from those previously published.