DOKUZ EYLÜL UNIVERSITY
GRADUATE SCHOOL OF NATURAL AND APPLIED SCIENCES

ARCHAEOSYS: AN ARCHAEOLOGICAL DATA MANAGEMENT SYSTEM

by
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İZMİR

ARCHAEOSYS: AN ARCHAEOLOGICAL DATA MANAGEMENT SYSTEM

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İsmail Hakkı PARLAK

ARCHAEOSYS: AN ARCHAEOLOGICAL DATA MANAGEMENT SYSTEM

ABSTRACT

In today's world, the transition from classical ways of data management to digital information management systems, and existent systems' rearrangement according to new technology, which began by the widespread of computers and computer networks, still continues with great momentum. Institutionalized organizations and government agencies already switched to custom designed computerized systems, whereas, establishments which can access less users or less budget are still using old fashioned data management techniques or they are limitedly trying to incorporate new technology to their existing data management systems. With regard to data management, archaeological excavation projects can be classified in the latter category since they could not fully switch to customized computer systems.

For the sake of better understanding of requirement, purpose and mechanisms of Archaeosys, which is the subject of this thesis, firstly, serving as a model for large scale archaeological excavation project, Smyrna Ancient City Excavation is examined and its procedural stages and data management methods at these stages are explained. After examining the stages of the archaeological excavation, development phases and procedures of Archaeosys are explained in details.

Finally, comparison of Archaeosys software with classical archaeological data management methods and similar software on the market is displayed, and by receiving opinions of experts, Archaeosys software is concluded to be successful on the basis of necessary benefit in the application field.

Keywords: Archaeological data management, archeological database, archaeological information system.

ARCHAEOSYS: BİR ARKEOLOJİK VERİ YÖNETİM SİSTEMİ

ÖZ

Bilgisayarların ve bilgisayar ağlarının yaygınlaşması ile başlayan, klasik bilgi yönetimi sistemlerinden dijital bilgi yönetimi sistemlerine geçiş ve mevcut sistemlerin gelişen teknolojiye göre yeniden düzenlenip geliştirilmesi, günümüzde hala olanca hızıyla devam etmektedir. Kurumsallaşmış organizasyonların ve resmi dairelerin kendileri için özel tasarlanmış bilgisayar sistemlerine geçiş yapmış olmalarına rağmen, daha az kullanıcıya hitap eden veya daha az bütçesi olan kurumlar, eskiden kalma bilgi yönetim tekniklerini kullanmakta ya da yeni teknolojiyi kısıtlı olanaklarla kendi bilgi sistemlerine dâhil etmeye çalışmaktadırlar. Bilgi yönetimi bakımından, arkeolojik kazı projeleri, özelleşmiş bilgisayar sistemlerine tamamen geçiş yapamadıkları için bu son bahsedilen grupta yer almaktadır.

Bu tezin konusu olan Archaeosys yazılımının gereksinim, amaç ve işleyişinin daha iyi aktarılabilmesi için öncelikle büyük çaplı bir arkeolojik kazı projesinin aşamaları ve bu aşamalarda kullanılan veri yönetim metotları anlatılmıştır. Arkeolojik kazı projeleri ile ilgili bilgi edinmek için Smirna Antik Kenti kazısı incelenmiştir. Arkeolojik kazı aşamalarının incelemesinden sonra Archaeosys yazılımının geliştirilme safhaları ve yöntemlerine değinilmiş; bu safhalar detayları ile anlatılmıştır.

Son olarak, Archaeosys yazılımının klasik arkeolojik veri yönetim metotları ve piyasadaki benzer diğer yazılımlar ile olan karşılaştırılması gösterilmiş ve bu konudaki uzmanların da görüşleri alınarak, Archaeosys uygulamasının geliştirilmiş olmasında, uygulama alanında gerekli faydanın sağlanmış olduğu tespit edilerek, başarı sağlanmış olduğu sonucuna varılmıştır.

Anahtar kelimeler: Arkeolojik veri yönetimi, arkeolojik veri tabanı, arkeolojik bilgi sistemi.

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CHAPTER ONE
INTRODUCTION

1.1 General

Technological innovations brought major changes to the field of information management. Before meeting sophisticated computers and computer networks, information management was a task that required paper forms, record collections, folios, archive rooms and warehouses, in other words, it was all based on papers and their storage management. Considering large scale data, paper based information management was a slow cumbersome system. For a new record insertion, usually, necessary forms were filled and stored in relevant files and storage rooms. Whenever any previously saved record was needed, one needed to retrieve it by seeking it manually within the previous records, which took a lot of time. Oliveira (2010) states that for retrieving information, professionals spend up to 50% of their times.

Especially for large scale organizations, paper based information management has several obvious disadvantages. Using paper for information management can be considered as inflexible. Written material on paper are fixed and they cannot be moved around. Moreover, paper is passive. Within paragraphs, sentences cannot be automatically rearranged nor can typing or grammar errors be automatically detected and corrected. When compared to files stored and transported on a DVD or transmitted electronically, large paper documents and folders are heavy and difficult to transport. These qualities are exactly the superiorities that electronic media has (Klotz, Rao, Johnson, & Withgott, 1997).

For the reasons mentioned above, by the availability of computers and computer networks in 1960s, paper based information management started to begin giving its place to computer based information management. Due to high costs, government agencies and large companies could transport their paper based systems to computerized databases initially (Taylor, 2001). Then, smaller companies and businesses could find the ability to shift their systems to computers as computers became cheaper by the acceleration of technological advances. Today, by the necessities and new opportunities brought by the internet, it is almost a must to switch to effective computerized systems to manage information handling (The Importance of a Good Information Management System, 2011).

Archaeological information management can be considered in semi-computerized information management category. Depending on the archaeological project's size and personnel, information management can be completely paper-based, non-specialized software based (using generic data management software like MS Excel, FileMaker etc.), or professionally computerized.

According to Eiteljorg and Limp, still, most of the archaeologists are not good at using technology. Moreover, many computer friendly archaeologists are still trying to re-invent the proverbial wheel. Worse yet, archaeologists who can produce useful and well prepared computer resources cannot reach to many colleagues who are knowledgeable enough to use those resources (Eiteljorg & Limp, 2008).

When Smyrna Ancient City Excavation was examined, it is observed that archaeological data management was carried out by using paper forms, notebooks and non-connected personal computers. Their ongoing system seemed to be cumbersome and hard to manage. There were several distinct nodes called "stations", and each station was processing information in its own private boundaries. Depending on the station, information was managed by computers, papers or a combination of both. Computerized stations were backing up and transfer data by regularly burning DVDs. So it was very hard to maintain synchronousness between stations. By observing these facts, a necessity for a custom software that would be used to manage Smyrna Excavation Project's archaeological data emerged; and this software is named Archaeosys.

1.2 Purpose

In this thesis, a solution to problem of archaeological data management is going to be offered as a web based software called Archaeosys. Archaeosys aims to bring about several positive attributes to archaeological data management such as consistency, traceability, security, safety and integrity.

Also a solution to compatibility of Archaeosys' user interface for different platforms such as desktops, tablets and smart phones is going to be presented by introducing responsive web design concepts.

Finally, Archaeosys and alternative computer based solutions to archaeological data management are going to be compared for displaying advantages and differences of Archaeosys in order to display the necessities and original value of the software.

1.3 Organization of the Thesis

This thesis includes six chapters. In this chapter (Chapter 1), an introduction to data management systems, focusing on archaeological data management, and purpose of the thesis are given. The remaining chapters of this thesis are organized as follows.

In Chapter 2, a literature review about archaeology, archaeological excavation management, digitalized archaeological data management techniques and archaeological data management software on the market are given.

In Chapter 3, stages and methods of archaeological excavation projects are described. Also, archaeological data management techniques, which are used throughout the archaeological excavations, are given.

In Chapter 4, internal structure of Archaeosys application is described in detail. Application's functional decomposition, data structures and database design are described.

In Chapter 5, Archaeosys application’s graphical user interface is shown in figures and functionalities of its forms and pages are described.

In the last chapter (Chapter 6), conclusions and several ideas for related future work are given.

CHAPTER TWO
RELATED WORK

Archaeological data management is a complex task and is evolving with the evolution of information management techniques and tools. Especially in large scale excavations, data management needs to be very well organized in order to ensure stability. One needs to have a good understanding of how archaeological excavation is performed for being able to design a successfully working archaeological information management system, whether paper based or digitalized. For obtaining knowledge of how to make a good working archaeological information management system, some studies were examined. Some of the key concepts of these studies are summarized below.

2.1 Literature Review

Drewett (2011) stated that the term archaeology can be defined in various different ways but to non-archaeologists, archaeology involves three elements as: the past, material remains and excavation. He listed the stages of an archaeological project as: planning, which can reduce the problems encountered on excavations if made properly, staff selection, tool selection, digging the site, recording archaeological excavations, post-fieldwork planning, interpreting the evidence and publishing the report.

White (2008) defined archaeology as “finding out about past human behavior by studying the material evidence left behind”. Similar to Drewett, she stated that an archaeological project consists of assembling a crew, gathering survey equipment - which includes old archaeological technology and the newest equipment, mapping the archaeological site, digging strata and levels, recording excavation information and finds. She found using computer software for data storage and processing archaeological data beneficial; and also stated the importance of backing up all computer work every day.

Eiteljorg and Limp (2008) stated that computers enable archaeologists to manage data more effectively and efficiently. They explained the benefits of a well-designed computer system for an archaeological project as follows:

- **Data Entry:** Automated checking of data entries can prevent errors, as can using pre-selected lists of allowed entries to prevent misspellings.

- **Data Editing:** Changes to the data can be tracked so that all changes can be identified and the original entries preserved for reference.

- **Data Storage:** Storage of all data in a central repository can keep files safe from loss or damage.

- **Data Presentation:** Data can be presented to different users in forms desired by those users.

- **Logic Enforcer:** Using computers encourages a clear, logical, and unambiguous system of data organization.

- **More Varied Information:** Many statistics can be produced.

In their paper, Anderson, Hermann, Miller and Yerka (2011) asserted that any institution performing archaeology must plan to collect and archive digital data. They presented entity relationship diagrams of an archaeological database and explained the entities in detail.

As a solution candidate to the requirement of digital archaeological data management system, Filemaker (2015) was examined. It is stated that FileMaker allows users to modify the database by dragging new elements into layouts, screens, or forms. It has features such as PDF creation, photo support, printing, signature capturing, chart support, scripting, ability to connect to a number of SQL databases including MySQL, SQL Server, and Oracle. It is also seen that it has different versions for Microsoft Windows, Mac OS, web browsers, iPad and iPhone.

As another solution candidate to the requirement of digital archaeological data management system, Integrated Archaeological Database (IADB) was examined. Rains (2014) defined IADB as a web application using modern AJAX programming techniques and explained that an IADB project database consists of data resources and the links, or connections between them. He explained the different types of resources as follows:

- **Finds:** Finds are sub-divided into Small Finds, Bulk Finds, Samples, Skeletons, Architectural Fragments and Structural Timbers.
- **Contexts:** The standard stratigraphic excavation unit.
- **Sets:** Sets consist of one or more Contexts, for example, the cut of a pit and its several fills, and can belong to a single Group.
- **Groups:** Groups consist of one or more Sets, for example, several associated pit Sets, and can belong to a single Phase.
- **Phases:** Phases consist of one or more Groups.
- **Objects:** Objects consist of any combination of Finds, Contexts, Sets, Groups, Phases and other Objects.
- **Images:** Images include photographs and other digital raster images such as scanned X-rays.
- **Illustrations:** These include any type of digital vector illustration which can be converted into SVG or DXF format.

- **Structure Diagrams:** A Structure Diagram can be thought of as a visual representation of, and an index into, a particularly aspect of the project database.

- **Documents:** Documents can be internal HTML documents created and edited within the IADB, externally created documents uploaded and stored within the IADB, links to external web resources, or references to paper documents.

- **Bibliography References:** Each IADB server maintains a global Bibliography, from which selected items are tagged for inclusion within individual Projects.

- **Built-in Editors:** The IADB includes online editors for creating and manipulating Structure Diagrams, creating and editing internal documents, and for digitizing single Context plans.

- **Tag Cloud:** Any number of user-defined tags may be applied to any resources within a project database.

- **Unique URIs:** Each IADB project, each Tagged list, each individual resource record, and each SQL Query in an IADB project database has a unique URI.

He also stated that a mobile version of IADB exists for the Apple iPad and iPad Mini which can work in offline mode so that data can be entered without a Wi-Fi connection.

Studies show that the field of archaeology can greatly benefit from having a modern, easy to use and cross-platform application which is directly archaeology oriented. But, existent alternatives on the market do not fully cover these specifications.

CHAPTER THREE
ARCHAEOLOGICAL EXCAVATION

In order to have a better understanding of Archaeosys software's necessity and principles, firstly, the details and stages of an archaeological excavation must be understood. Without knowing enough of what it takes to sustain a successful archaeological excavation, it is not possible to develop a software as a solution to challenges that the nature of archaeological process brings.

Archaeological excavation is not a straightforward and simple task and surely it is not just digging out fossils and artefacts and storing them in storerooms. An archaeological excavation process takes huge amount of work and planning from beginning to the end. It is better to divide the whole process into sub topics and examine each one rather than taking the whole process into consideration.

3.1 Planning and Preparation

Assuming excavation process as the most essential part of any archaeological fieldwork is a mistake. In fact, without well planned research excavations, discipline of archaeology could become as fossilized as many of the sites it studies (Drewett, 2011). It is obvious that a well-planned project can achieve success more likely than a poorly planned one.

Keeping in mind the process of planning and preparation has great importance for any archaeological excavation, this task can be examined in several sub topics as follows.

3.1.1 Deciding the Scope and Aim of the Excavation

What is expected from the excavation, deciding what to search for and deciding how far the excavation will go is the first step of the planning. Archaeologists do not go and dig random places for random artefacts. Firstly, the excavation's purpose should be clearly decided. Without determining what to be expected from the excavation, a project may get over saturated with the multiplicity of the findings.

Considering Smyrna Ancient City Excavation, the aim of the excavation was to resume the unfinished Agora excavations started in 1930s and 1980s and discover structures belonging to archaic period (“İzmir - Agora,” 2012). So, both monetary and physical resources have been being spent mostly focusing on the main objective. If this was not the case, being a host to very diverse cultures throughout the history, the excavation field could distract the crew from accomplishing their goal.

3.1.2 Legal Permission and Funding

Before attempting to any action with regard to archaeological excavation, legal permits from the related governmental agency must be acquired. The process of getting the archaeological permit varies between countries. In Turkey, permits for archaeological excavations should be obtained from Ministry of Culture and Tourism. In order to get the permit for excavation, necessary forms must be prepared under the supervision of excavation manager and handed over to ministry. Detailed information about this process’ prescription can be reached at the website of Ministry of Culture and Tourism (T.R. Ministry of Culture and Tourism, 2015).

Funding is the vital energy that brings any archaeological project to life. Without enough monetary supplement, it is impossible to maintain, even start the project. Employment of personnel, supplying their food and drinks, gathering required equipment and building the laboratories and shelters in excavation site is not a low cost task. For Smyrna Ancient City Excavation, both governmental and private sponsoring were needed to sustain such a large scale project. Private sponsors had to be approved by the ministry before they could start to fund the project. Detailed information for formal sponsorship can also be found at the ministry’s website.

3.1.3 Personnel Selection

Selecting right personnel according to project's requirements and scope is crucial for success. Amount of stuff needed for the excavation depends on the size of excavation and the type of work to be done. An archaeological excavation project needs a project manager or director. This person directs policymaking on all aspects of the project whether and decides academic, practical and logistical issues. On large scale projects this position may be too great for one person to manage; if so, an assistant director may be appointed to administer certain aspects of the project (Drewett, 2011).

For different tasks, different types of personnel are needed. For digging material out by shovels and diggers, it is better to employ workers. There will be a group of academicians for doing the scientific work. Experts are needed to clean and restore the Finds. Interns will be provided opportunity to study the excavation process. There will be technology experts to set up technological devices, such as computers and networks. There should be photographers and computer aided drawing experts. Depending on the project, this list can be elongated or shortened.

3.1.3 Authority and Management Diagram

Every personnel's or personnel group's authority must be clearly defined. It is very important to determine who is in charge of what. Otherwise, ambiguous jurisdiction causes unhealthy relation between personnel. A well-established chain of command should be declared to all personnel in order to prevent future frictions. As an example, management diagram of Agora Excavation is illustrated in Figure 3.1.

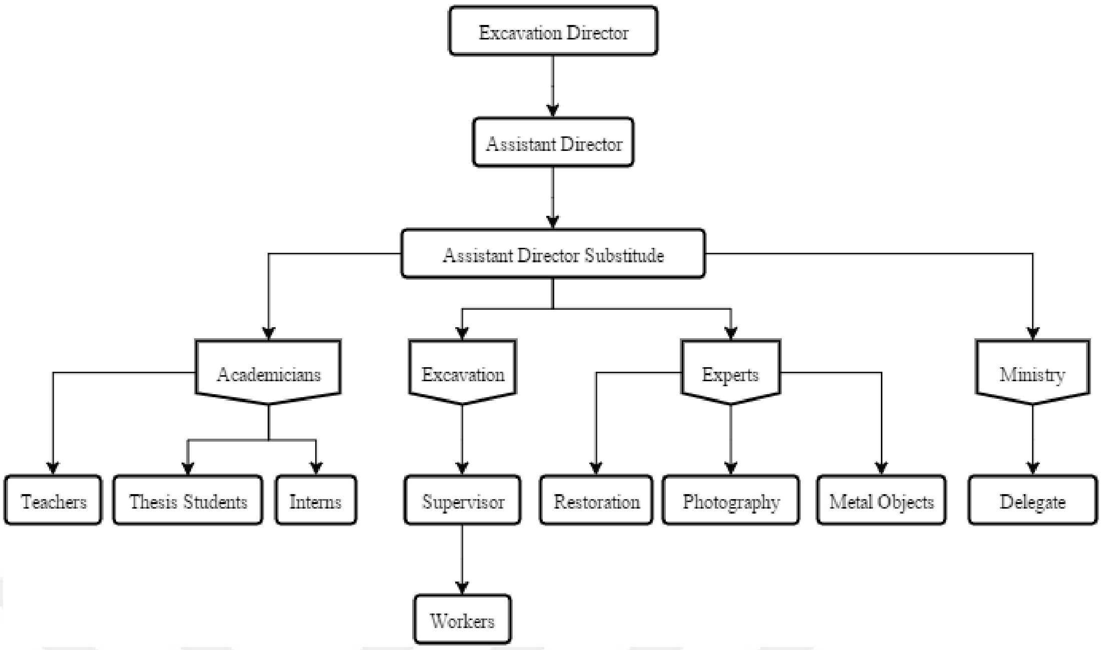


Figure 3.1 Management and classification diagram.

There will be critical regions of the excavation buildings such as laboratories, warehouse, document archives and safety deposit boxes. They must be made accessible only to restricted personnel. Finds that are dug out of the excavation site are under the ownership of government. Losing any piece of information or any Find can lead to serious legal acts.

3.1.4 Preparing the Equipment

Despite the technological improvements, some archaeological equipment haven't changed too much. Selection of tools depend on excavation project's target and scope. Some tools that are fused with the concept of archaeology can be listed as: shovels, trowels, knives, spoons, spatulas, brushes, buckets, plastic bags, cases, water tanks, wheelbarrows, markers, paper forms, stickers, notebooks, compass, strings and ropes, gloves, colored tapes etc.

Some equipment related to security can be listed as: helmets, construction clothing and first aid supply.

Depending on the project, heavy vehicles such as bulldozers, tractors, snow cats, graders, skit-steer loaders, excavators and forklifts can be utilized.

In today’s world, archaeologists are also benefitting the new technological equipment. Professional cameras and computer aided design software can be used for creating the images of discovered artefacts. Walky-talkies and mobile phones can be used for communication in the field. Tablets and smart phones can be used as a source of mobile computing devices. GPS units can be used for detecting the location’s coordinates. Computers with special software and computer networks can be used for storing and managing all the excavation and artefacts information.

3.2 Field Investigation and Mapping

After sorting out the paperwork between excavation director and governmental agencies, field investigation’s turn comes. Archaeologists simply walk over open ground, inspecting the surface for artifacts. Or they dig small shovel tests to see what’s hidden below ground. Site discoveries are written down and artifact finds are stored in bags with written notes about where they were found.

Most of the archaeological examination consists of driving around looking for standing ruins or open ground where the surface is visible and suitable for finding the artifacts. This surface inspection is the most common way of finding sites.

Where ground is covered with vegetation, archaeologists look for exposed places, like unsealed roads or milled earth. Any disturbed, open ground can expose artifacts (White, 2008).

After examining the field and learning its characteristics, archaeologists can start to prepare a detailed map and plan of the excavation site. In this phase of planning, alongside of a mapping expert, special mapping equipment is needed for precise planning and consistent results, especially for large excavation fields. Global positioning system (GPS) can serve a basic data source. Site location can be recorded by GPS receivers and then it can be saved to a computer (Eiteljorg & Limp, 2008). Geographic information systems (GIS) and remote sensing (RS) are being used extensively for mapping, modeling, and managing archaeological data (Wiseman, Christensen, & Nicholson, n.d.). Other mapping equipment can be listed as: transits (a mapping device consisting essentially of a telescope, a big compass, and a tripod), plane tables, alidades, theodolites, electronic distance measuring devices (EDM), total stations and 3D laser scanners (White, 2008).

An archaeological excavation project can be composed of different sites. For example, Smyrna Ancient City Excavation Project consists of different sites such as Agora, Pagos, and Zeus Akraios Temple etc. So mapping for each site has to be done separately since they are on different geographical locations. A project may even cover sites that are in different cities.

Depending on the size and structural composition, an archaeological site can be divided into sectors as displayed in Figure 3.2. Each sector is a region of the site containing a distinctive structure and theme. During the archaeological process within a site, each sector is dealt as a singular entity.

Figure 3.2 Some of the sectors of Agora Site (Ersoy & Şakar, 2015).

When preparing the excavation site's map, each site or sector is divided in smaller sample units.

> A sample unit is the unit of investigation, defined by either arbitrary or non-arbitrary criteria. Non-arbitrary sample units correspond either to natural areas, such as microenvironments, or to cultural entities, such as rooms, houses, or sites. Arbitrary sample units are spatial divisions with no inherent natural or cultural relevance, such as a grid system (equal-size squares) (Ashmore & Sharer, 1989, p. 76).

Examining Smyrna Ancient City Excavation's Agora Site, arbitrary sample units were drawn on site map, forming a grid. These sample units were called as plan-squares by Agora team. As can be seen in Figure 3.3, each plan-square is labelled like Excel's cell labeling system: such as B6, B7… C6, C7… H6, H7… H10. Due to project's privacy policy, the actual plan-square overlay is not displayed here.

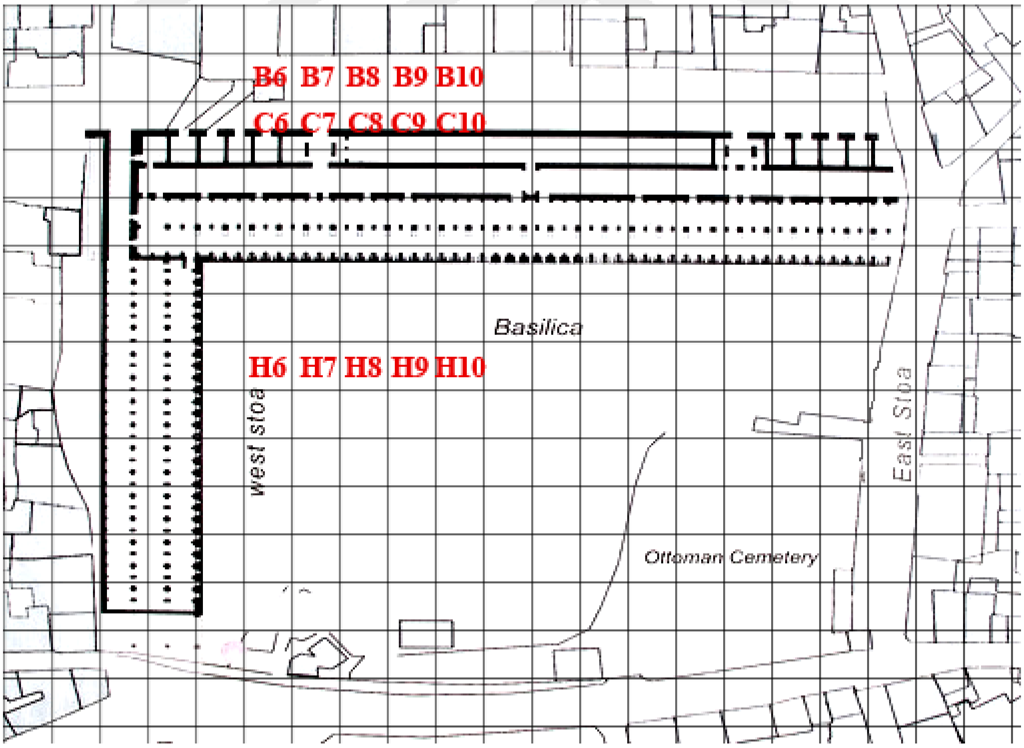


Figure 3.3 A representational plan showing plan-squares of Agora Site.

During the excavation process, maintaining the excavation plan according to plan-squares has great importance. Each discovered Find's plan-square must be noted down for future use. Without knowing the Finds' original positions in excavation field, it is impossible to obtain a conclusion from excavation data.

3.3 Excavation Planning

Knowing the determined boundaries of archaeological field, having the planned grid system in hand and knowing what to look for when excavating, it is possible to plan the whole digging process. Planning the excavation before getting down to work can save great time and yields to a lesser erroneous phase.

First of all, digging procedures for each sectors must be determined. Will the crew use heavy machinery or smaller equipment like shoves and trowels? What will be the depth of digging layers? Will these layers be arbitrary or have fixed depth or combination of both? What types of casing will be used for Finds? Where will the washing unit be placed? Pre determining answers to these types of questions help having a smooth digging process.

Another important matter is, excavation forms and paper work for governmental correspondence should be prepared before starting to dig. Every discovered Find's necessary information must be stored at some medium in detail. Since every bit of Finds which are discovered in excavation field is under ownership of ministry, keeping track of each item is very important. Otherwise, lost or stolen material can cause legal adversities.

Forms that are used for storing Finds' information do not have to be on paper. They could be digital too. For example in Smyrna Ancient City Excavation, some of the forms are prepared with FileMaker Pro, which is a consumer database application, Microsoft Word and Microsoft Excel. A cleverly prepared digital medium is a key for success in post excavation analysis.

In order to have a neat archive, storage system for accumulated forms and data must be pre planned. A fluently working system for classification and conservation of paper based and digital forms should be designed. There should be a system for backing up digital data regularly. Also copies of paper forms and governmental documents must be kept in archive. In case of any accident, the system can be restored to last check point to prevent losing huge amounts of data.

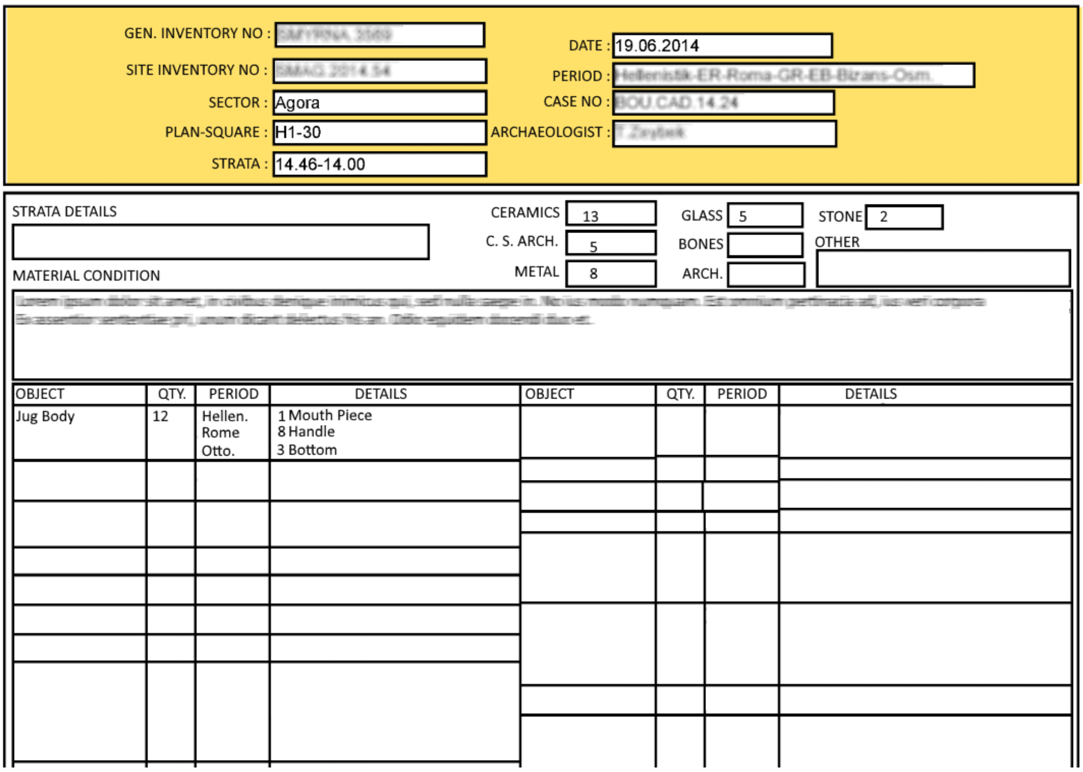
After being unearthed, the Finds visit several places, rooms and buildings. These placed are called “stations”. In each station a specific task is performed on Finds. A station may be a part of excavation field, an area, a room or a building. For large scale and long term project, if there is enough budget, it is clever to build the stations close to excavation area. Otherwise, transportation of archaeological material and Finds consumes a great deal of time, effort and money. Stations in Agora Site can be listed as following:

- **Excavation Station:** Any place in which archaeologically valuable material is found. Excavation field is also called excavation station. Even though this station does not have any roof or resemblance to buildings, for setting up clear frontiers between different types of working environment, this unit is also named as station.

- **Cleaning Station:** After being dug out, all coarse dirt should be removed from the Finds in this unit. Using water and small tools like toothbrushes, initial cleaning of all Finds, which are brought from excavation station, is done here. After washing, wet material is exposed to warm air for drying.

- **Pre Evaluation Station:** After rough cleaning, Finds are transferred to this station. As shown in Figure 3.4, in this station, archaeologists take a photo of all Finds with their case labels. After taking photo, Finds’ information such as their quantity, historical period in which they belong to, explanatory information, object type, condition and properties of the layer in which they were found is entered in a form. This form is called “case list form”. A section of a sample case list form is shown in Figure 3.5. After filling the case list form, archaeologically high valued items are sent to drawing station. Other items are sent to related stations or to storage.

Figure 3.4 A photography of Finds, taken in pre evaluation station.



GEN. INVENTORY NO : [illegible]
SITE INVENTORY NO : [illegible]
SECTOR : Agora
PLAN-SQUARE : H1-30
STRATA : 14.46-14.00
DATE : 19.06.2014
PERIOD : [illegible]
CASE NO : [illegible]
ARCHAEOLOGIST : [illegible]

STRATA DETAILS
MATERIAL CONDITION
[illegible]

CERAMICS 13 | GLASS 5 | STONE 2
C. S. ARCH. 5 | BONES | OTHER
METAL 8 | ARCH.

OBJECT	QTY.	PERIOD	DETAILS	OBJECT	QTY.	PERIOD	DETAILS
Jug Body	12	Hellen. Rome Otto.	1 Mouth Piece 8 Handle 3 Bottom				

Figure 3.5 A portion of a sample case list form.

- **Drawing Station:** Finds, which have high archaeological value so that they can be exhibited in museums, arrive this station. Their close up image is taken with a sophisticated camera. And experts make technical drawings both on paper and computer aided design software such as CorelDRAW and AutoCAD. Samples of generated images at drawing station can be seen in Figure 3.6.

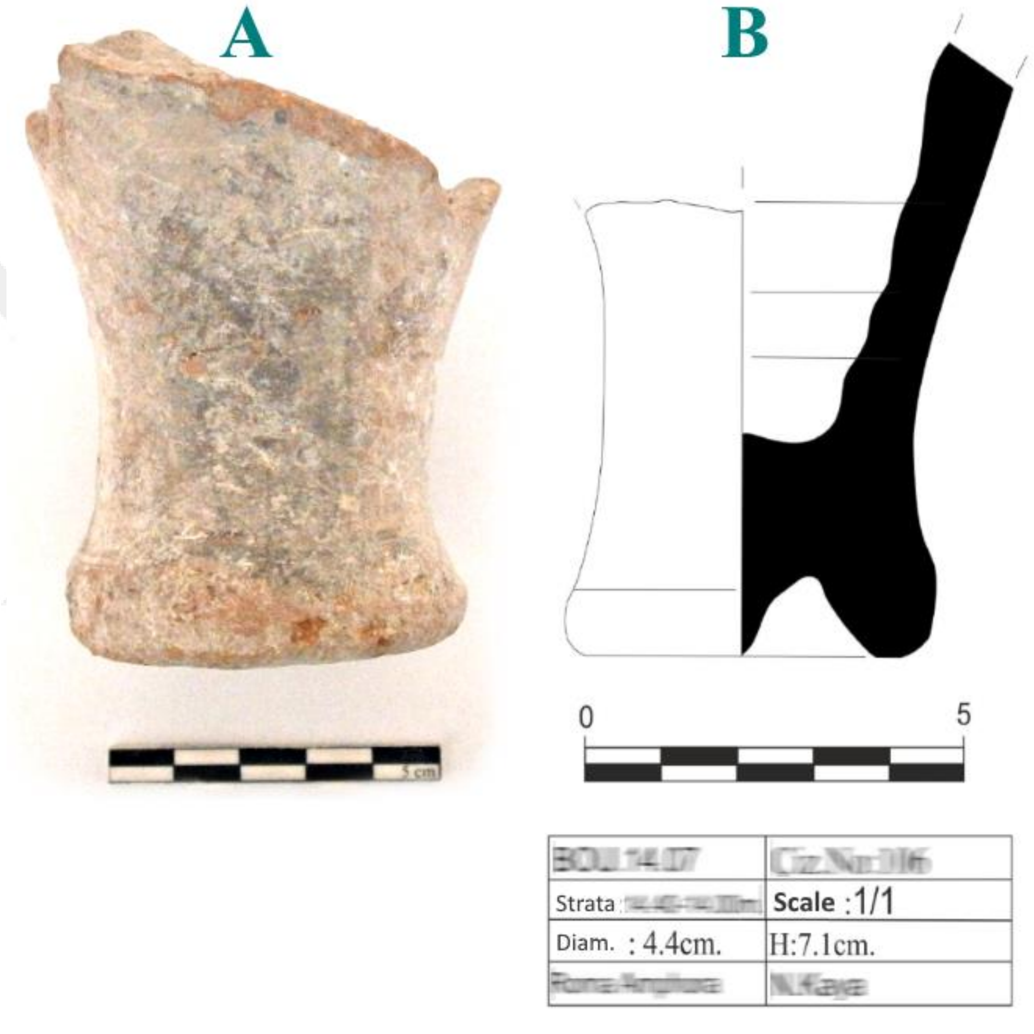


Figure 3.6 Close up photograph (A) and technical drawing (B) of a Find, from drawing station.

After taking a detailed photo and drawing the technical images, experts and archaeologists in this station fill a digital form, called “piece form”, with their observations about processed item. As partially displayed in Figure 3.7, this form contains information fields such as where and when this item was found, the layer it was found, its type, the historical period it belongs to, its modal properties, and its material properties.

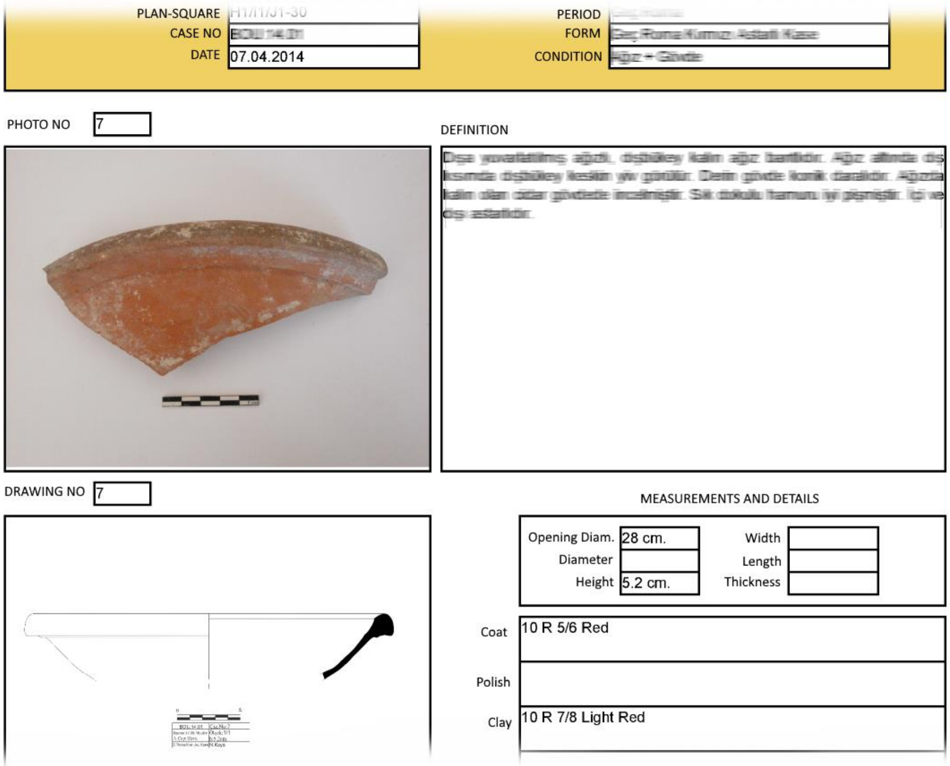

PLAN-SQUARE H1/I1/J1-30
CASE NO
DATE 07.04.2014
PERIOD
FORM
CONDITION

PHOTO NO 7

DEFINITION

DRAWING NO 7

MEASUREMENTS AND DETAILS

Opening Diam.	28 cm.	Width	
Diameter		Length	
Height	5.2 cm.	Thickness	

Coat	10 R 5/6 Red
Polish	
Clay	10 R 7/8 Light Red

Figure 3.7 A section of a “piece form”, taken from drawing station.

- **Ceramics Station:** For fine inspection, ceramic items visit this station. Experts and archaeologists examine the Finds and they decide the pieces’ archaeological value. They may spare some of the Finds placing them into new separate bags or they may discard some pieces. For each bag, a new sticker must be generated and filled with data regarding to its contents. If Finds need reconstruction or detailed cleaning, they are sent to restoration station. If found convenient, Finds go to warehouse for storing.

- **Restoration Station:** Most of the uncovered Finds are not in good shape, especially if they are very old or covered with thick layers of earth. Metal Finds are usually corroded and misshaped whereas ceramics are usually found to be broken into pieces and fused with soil. In order to see what a Find was like in its original form, they need to be cured by experts. Restoration station is the laboratory in which this curing is applied. An image of a cured water container is shown in Figure 3.8.

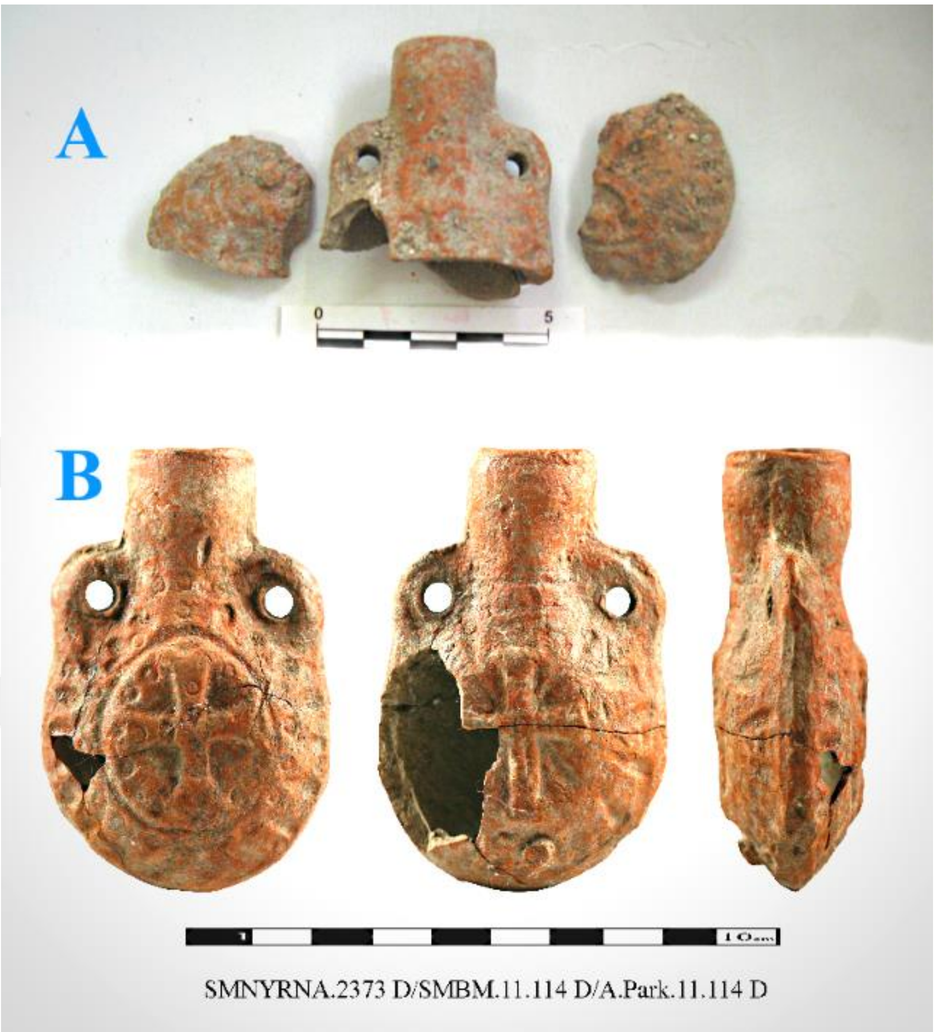


Figure 3.8 A water container before (A) and after (B) restoration.

Not every Find goes under restoration process, only the ones with higher archaeological values are treated. After treatment, restored item goes back to the station which it was sent from.

- **Coin Station:** Coins are treated differently since they have a different class of type and they are monetarily valuable. Also very accurate information can be extracted by examining the figures on coins, as shown in Figure 3.9. When dug out, coins go directly to coin station for analysis. In coin station, experts decide whether the coin is archaeologically valuable or not. If they find the investigated coin to be valuable they begin processing their work. If coin is not in condition, it is sent to restoration. In coin station, detailed photographs of coins are taken and coins are placed in special envelopes. After writing the descriptive data on envelope, coins are stored in a private safe.

Figure 3.9 Image of a coin found in Agora (Ersoy, 2012).

Last stage of planning the excavation is designing a storage facility for Finds. Depending on the project, a wide range of items may be discovered and they may take up huge space. If this is the case, a warehouse must be assigned for storing all the Finds. If there is enough resource, warehouse must be built at a close distance to excavation field so that transportation of discovered Finds to warehouse does not take too much effort and time. As shown in Figure 3.10, Agora site has the opportunity of having a close by warehouse.

Within the warehouse, placing and classification of Finds must be well planned. Placing a new Find inside warehouse should not be random but should follow a placement plan. It may be suitable to divide the warehouse into sectors for different types of Finds. Some Finds will be very large in size such as large pots, statues and structural pieces. Others may be very small such as coins and small figures. For large items, it is easier to place them close to ground and if possible, building platforms having some distance off the ground may also help to use the available storage space economically. For smaller items, building a system resembling in libraries may be handy.

A well prepared warehouse and storing method does not just help keeping all of the Finds but it also is very helpful for retrieving the stored items. Academicians and archaeologists will need to extract information about their findings after some amount of discoveries. So, a well-planned and placed warehouse shortens time for seeking and finding any item previously stored.

Figure 3.10 (A) excavation station, (B) other stations and labs, (C) warehouse of Agora.

3.4 Digging and Recording

Having legal permissions in hand, preparing the equipment and the crew, preparing the map of excavation area and drawing the plan-squares, designing recording forms and computer systems and designing the stations, labs and warehouse, finally the process of digging can begin.

First thing to do is to lay out the plan-squares. In Agora excavation, they mark all four corners of plan-squares with stakes and then tie ropes to stakes for marking the borders of plan-squares, similar to the photograph displayed in Figure 3.11.

Figure 3.11 Excavation performed within a digging unit (plan-square). Borders are marked with ropes (Archaeological Excavation – Destructive?, 2012).

As stated before, keeping track of the origins of discovered Finds has vital importance for archaeological studies. Exact three dimensional position must be recorded for each Find in order to gain the ability to extract information about the original state of discovered items and structures. A plan-square can provide two dimensional position information. Whereas keeping the depth of discovery from the surface point of plan-square adds the third dimension. So it is also very important to make the digging layer by layer. Each layer's depth from surface and soil properties are also recorded for constructing a three dimensional meaning of discoveries.

All portable Finds can be placed in cases and then sent to stations and labs for further assessment. Each case is labeled with data consisting of site, sector, plan-square and layer information for the contained pieces. Items in the case can be tracked later by querying this case label. But in Agora, there are also numerous immobile Finds such as pillars, walls, arches, buildings, sepulchers and large statues. Since this type of Finds cannot be transferred, they are studied in their place of discovery. Instead of putting them into cases, their case label information are written on them with water resistant markers and to prevent wearing out writings are sealed with lacquer.

Recording archaeological data can take several forms such as: written records, drawn records, camera records and digital records.

- Written records generally include everything written on notebooks and forms. All information about the excavation field must be noted down. Physical properties, soil properties, coordinates of the site and plans about the site must be noted down clearly. These should be clear enough to let another person understand what procedures are taking place throughout the excavation. If managerial personnel change, new comers should be able to understand what was going on clearly.

- Drawn records include mapping and plan-square plans, illustrations and sketches. Cross section drawings of created pits are also in this group.

- Camera records are videos and photography of the site and findings. Capturing images throughout the excavation helps keep tracking of initial state of the field and Finds for further logical assembly. A scale and direction mark (usually pointed to north) must be included within the photo/video when necessary.

- Digital records are occupying increasingly large portions of data as technology advances and spreads. This portion of records include all digital forms and also records created by digital cameras. From text files to spreadsheets, primitive databases to advanced software, all of computerized data are in this category. At the present time, archaeologists are also using tablets and smart phones for recording digital data. Mobile devices let archaeologists gain mobility with software. But PCs and laptops are preferred for scientific analysis since they have higher computation power.

3.5 Analyzing and Interpreting the Acquired Data

After all the planning, preparation, digging and recording, the last and most important part of an archaeological excavation project comes: analyzing and interpreting all the acquired information throughout the whole process. This is the stage that determines how successful the project was. Recording the details of excavation field, pits and Finds should have been made very precise, well organized and meticulously. Otherwise, seeing the bigger picture by bringing the smaller pieces together may not be possible.

Archaeologists may work with anthropologists, paleontologists, biologists, historians, and chemists etc. to reconstruct the past. Getting help from different disciplines yields extracting more detailed and precise data from Finds and recordings. All the gathered data then should be put on the table and studied for discovering past human behaviors and cultural systems. Without being able to discover human past, archaeology would not be any different than treasure hunting.

An effective procedure for interpreting meaning from loads of data is to make use of tables and charts. Creating tables by computers rather than paper has great advantages. Even by using spreadsheets it is possible to sort the table column-wise, filter the results, search within large data or apply statistical functions. However, as the data grows larger, it get harder to manage it within a single spreadsheet or file. Within a simple file, executing complex tasks on very large data can crash the computer. Using custom software built for archaeological purposes or a database management system (DBMS) is more preferable for larger data.

Tables are handy in displaying textual and numerical data. Whereas, charts are graphical displays of information wherein the information is graphically illustrated by bars, lines, or slices. Charts are used for defining the relationship between large amounts of information and their parts and they can make it easier to read and understand (Emelda, 2011). According to archaeological needs charts may be area based, depth based or they may be based on Finds.

- Area based charts are useful for deriving information that is related to sections of sectors. What types of Finds are found in across the site, what historical periods they belong to, what their materials are… All these types of information can be understood by examining area based charts.

- Depth based charts are useful for understanding time based changes. As time goes on, new layers are composed on top of each other. Deeper buried Finds can be assumed to be older than shallow buried ones. So, including surface Finds in depth based charts may not be rewarding when studying time based changes over an area.

- Find based charts, as displayed in Figure 3.12, can deliver information with regard to type, shape, painting, material composition and area of use for artifacts. A culture’s level of welfare, technology, religious beliefs, artistic tendencies, regime, economic system, environment, ethnicity and social structure can be derived by studying these types of charts.

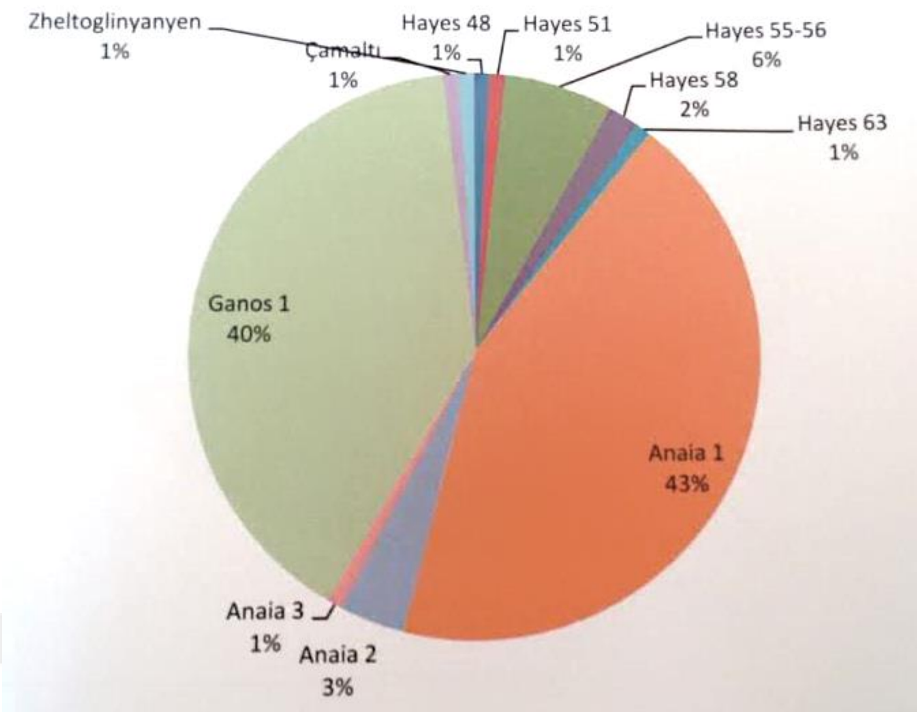


Figure 3.12 A pie chart sample from Smyrna Excavation (Ersoy & Şakar, 2015).

By reading tables and charts, examining the Finds and making use of historical data and combining all of these with today's knowledge and wisdom, archaeologists can build the stories of the past humans lives, and write field records; and finally, share their findings with other people. Without publishing a report, an archaeological project cannot be accepted as complete and finished. Archaeological journals should be preferred for publishing reports. Also, conferences provide opportunities for sharing the reports and findings with other colleagues and people who have interest in the area of archaeology.

CHAPTER FOUR
ARCHITECTURE OF ARCHAEOSYS

In chapter three, an archaeological excavation process is explained from start to end without getting into excessive details. In this chapter, combining chapter three's information with software engineering facilities, Archaeosys Application's development process and structure will be put forth.

4.1 Preliminary Study and Requirement Analysis

Archaeosys project was officially started in 2014. But before it started, an idea of building a more efficient computerized system for Smyrna Ancient City Excavation's data management had already been discussed between scholars of Dokuz Eylül University (DEU). This initial idea was recorded on sketch papers without thorough details. After evaluating the circumstances, it is decided to begin developing the application. Soon after, meetings with Smyrna Ancient City Excavation crew are arranged in order to determine the details and scope of the application.

4.1.1 Preliminary Study

First major step was to learn about the workflow and data management strategies of Agora Excavation Project, which is a site of Smyrna Ancient City Excavation. Alongside of visiting the excavation field and having meetings with the crew frequently, also resources about archaeological process were studied in order to have a better understanding of archaeological excavation. Their existing data management system was studied in detail and their demands for the improvement of their existing system were settled.

Detailed flow charts were prepared at DEU Computer Engineering Department. Firstly, preparing the flowcharts was the choice of action, because, flowcharts are uncomplicated visual representations of the system and they are easy to understand by people belong to all branches of science. These flowcharts, as can be partially seen in Figure 4.1, represent the dataflow of Agora Excavation.

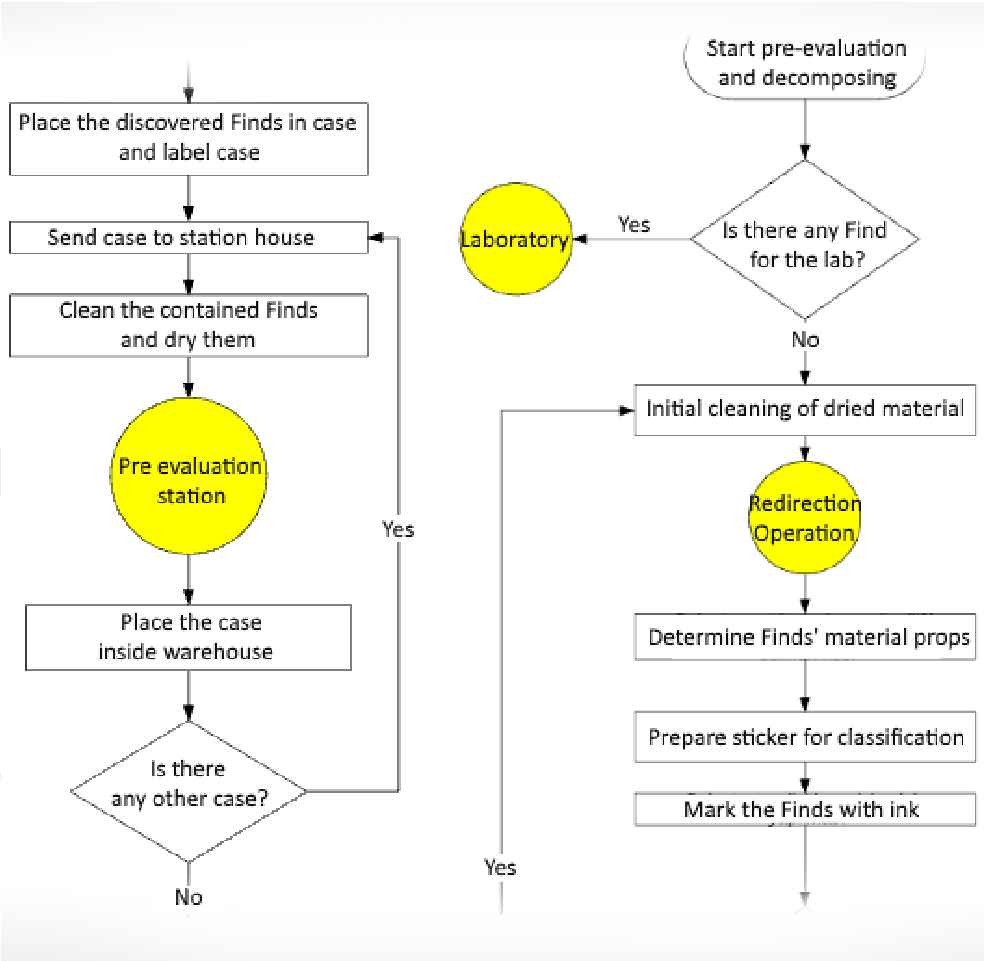


Figure 4.1 A section of Agora Excavation's workflow flowchart.

4.1.2 Requirement Analysis

After coming to an agreement on flowcharts of Agora Excavation's workflow, process of requirement analysis started. According to Institute of Electrical and Electronics Engineers (1990), requirement analysis can be defined as "the process of studying user needs to arrive at a definition of system, hardware, or software requirements" (pp. 62-63).

In Agora Site of Smyrna Ancient City Excavation Project, data management process was being carried on by entering the data into non centralized data pools. In every station, data was being entered into FileMaker files, Word and Excel documents.

One handicap of the existing system was the lacking of having a connected system. Documents were transferred to a main computer room on a monthly basis for archiving. In archive room there were two separate computers containing the same data, one backing up the other. Transferring and backing up the data manually may not be a big problem for small scaled projects, but thinking of Smyrna Ancient City Excavation, which has started in 2007 and still continues today, it takes huge amount of time and effort when considering total work done so far.

Another handicap of the existing system was having excessively growing FileMaker files. Within some stations, as more and more data was entered, FileMaker files were growing up to hundreds of megabytes even gigabytes. When a FileMaker file gets too large, process of entering new data slows down drastically. Also, Agora crew reported that too large FileMaker files were damaged occasionally, and damaged files could not be opened. A large damaged file means losing large data.

Lacking an interconnected system also brings the inability of tracking the data. If excavation director wants to search any data, he has to first search the station in which the data is processed and then search within the station’s computer.

Finally, keeping the data in several different types of mediums makes it harder to keep track of excavation process. Keeping notebooks for some sort of data, and using computers for other types can reduce the efficiency of archaeological data management. Searching within the decks of paper is harder and backing up paper based data is more expensive when compared to computers. And it may be difficult to decide where to look at first place: is searched data in notebooks or in any of the computers?

Studying and understanding the needs and facts above, the phase of deciding the technical aspects and specifications of the application started. Archaeosys, as a final product would have features and goals such as:

- Having Turkish as user interface language. Archaeosys would be accessible for workers, students, academicians etc. In order to be user friendly and easily understandable by all types of users from Smyrna Excavation team, Turkish is chosen to be the language of the application.

- Providing a connection between work stations. Since archaeological finds travel between stations, their recorded data must be able to accompany them too. A station should be able to see the incoming Finds and send them to relevant stations when done with them.

- Having a central and reliable database. System must be able to store all the data in a database server. Database server must back up its database automatically in pre-determined intervals. Also database must be fast enough execute queries in short time and be secure.

- Being able to provide a role based authorization system. Excavation project's hierarchy must be reflected to the system. Every personnel must be able to access only his associated section of the system. Administrator should be able to assign roles to each personnel and should be able to freeze a personnel's account.

- Fast working and having modern features. System must respond quickly to user actions. Non responding screens are not desired. Also the look and feel of the system should catch up with the modern trends.

- Adapting to different types of devices. System must be accessible from PCs, tablets and smart phones. Since every genre of devices have different screen dimensions and resolutions, graphical user interface must adapt to a variety of devices. Also system must work fluently on these different types of machines.

In order to meet the criteria listed above, technological components of the application are chosen as:

- **Microsoft SQL Server 2014:** Microsoft SQL Server is a relational database management system (RDBMS). It can be accessed over a network or internet for storing and retrieving data. SQL Server 2014 is selected to be the main data management system simply because it can very well serve as a central unit for devices that have internet connection. It has great advantages such as: automatically backing up the database in determined time intervals, having support from Microsoft, allowing to execute transactions and having support for Transact-SQL.

  Compared to previous SQL Server versions, SQL Server 2014 has a great new feature called In-Memory OLTP (Online Transaction Processing) (also known as Hekaton). In-Memory OLTP allows moving individual tables to special in-memory structures, hence, increase the performance boost around 30 times (McCown, 2014). SQL Server 2014 also has a new feature called Buffer Pool Extension. When combined with SSDs, it can improve the disk I/O throughput significantly (Microsoft, 2016b).

- **Windows Server 2012 and IIS 8.0:** Windows Server is an operating system (OS), especially designed for server machines. It supports remote desktop connection, ability to manage different user accounts and it has Active Directory service. Windows Server 2012 includes Internet Information Services (IIS) version 8.0. IIS is a web server which supports HTTP, HTTPS, FTP and SMTP. IIS 8.0 includes new features such as Server Name Indication (SNI), support for centralized SSL, CPU throttling and Web Socket support. ASP.NET web applications can be hosted and managed on Windows Servers with IIS installation (Microsoft, 2016c).

- **.NET Framework 4.5:** .NET Framework is developed by Microsoft as an application development platform. By providing language interoperability, .NET Framework allows interaction of different programming languages. Programs written for .NET Framework run in Common Language Runtime (CLR) environment. CLR is a virtual machine that enables program codes to be converted to machine codes to be executed on CPU. .NET Framework version 4.5 has powerful capabilities such as parallel programming enhancements introducing Async and Await code markers, reading and writing HTTP Requests/Responses asynchronously and ability to set the culture for application domain (Microsoft, 2016a).

- **Bootstrap:** For meeting the requirement of adaptation to a wide range of devices, two alternatives were discussed before beginning to develop the application. First alternative was to develop a web application which can be accessed by computers' internet browsers and also to develop its mobile versions for iOS and Android installed tablets and smart phones. The second alternative was to develop a single web application which could adapt its GUI to different screen sizes for computers, tablets and smart phones by using responsive design frameworks.

Keeping the idea of Archaeosys in focus, an assessment was done for comparing the alternatives for native mobile development and responsive design development in several aspects. Assessment results are shown in Table 4.1.

Table 4.1 Comparison of native mobile development and responsive web design development for Archaeosys software.

	Native Mobile Design	**Responsive Web Design**
Cross Platform	✘	✓
Works Faster	✓	✘
Less Coding Effort	✘	✓
Access to Hardware	✓	✘
Easier to Install	✘	✓
Easier to Update	✘	✓
Easier to Maintain	✘	✓

Advantages of native mobile applications are: they provide a better user experience since their user interface works faster and more smoothly, and they have direct access to device's hardware such as camera. But developing application's mobile versions would require labor at least twice as much as developing a responsively designed web application. Responsive web application also has advantages such as: it does not require an installment on device since it runs on internet browser, it is easier to maintain and easier to update.

Analyzing the assessment results given above, developing the application's user interface by responsive web design techniques was found more suitable. Twitter's Bootstrap library was chosen for this task. Bootstrap framework contains HTML and CSS based templates and JavaScript extensions for developing web applications which can automatically adapt to different screen resolutions (Otto & Thornton, 2015).

- **jQuery:** jQuery is an open source JavaScript library. "It makes things like HTML document traversal and manipulation, event handling, animation, and Ajax much simpler with an easy-to-use API that works across a multitude of browsers" ("jQuery," 2016). jQuery has mobile support and it greatly reduces the effort to write JavaScript for front end development. Along with Bootstrap, jQuery provides an environment in which developers can easily build web applications that have modern features like AJAX and responsiveness.

4.2 System Architecture

Archaeosys system is designed to meet the requirements of a robust, modern and secure archaeological data management system. It is secure, decorated with contemporary look and feel and it connects the whole excavation team under the same theme.

In order to understand the application, it is better to follow a top-down approach for examining its structural design. First, a holistic and rough sketch of the system will be displayed, and then, details of each part will be explained in following sections.

4.2.1 Architectural Design

At highest level, as displayed in Figure 4.2, Archaeosys application can be abstracted into three components: graphical user interface, ASP.NET server and SQL server.

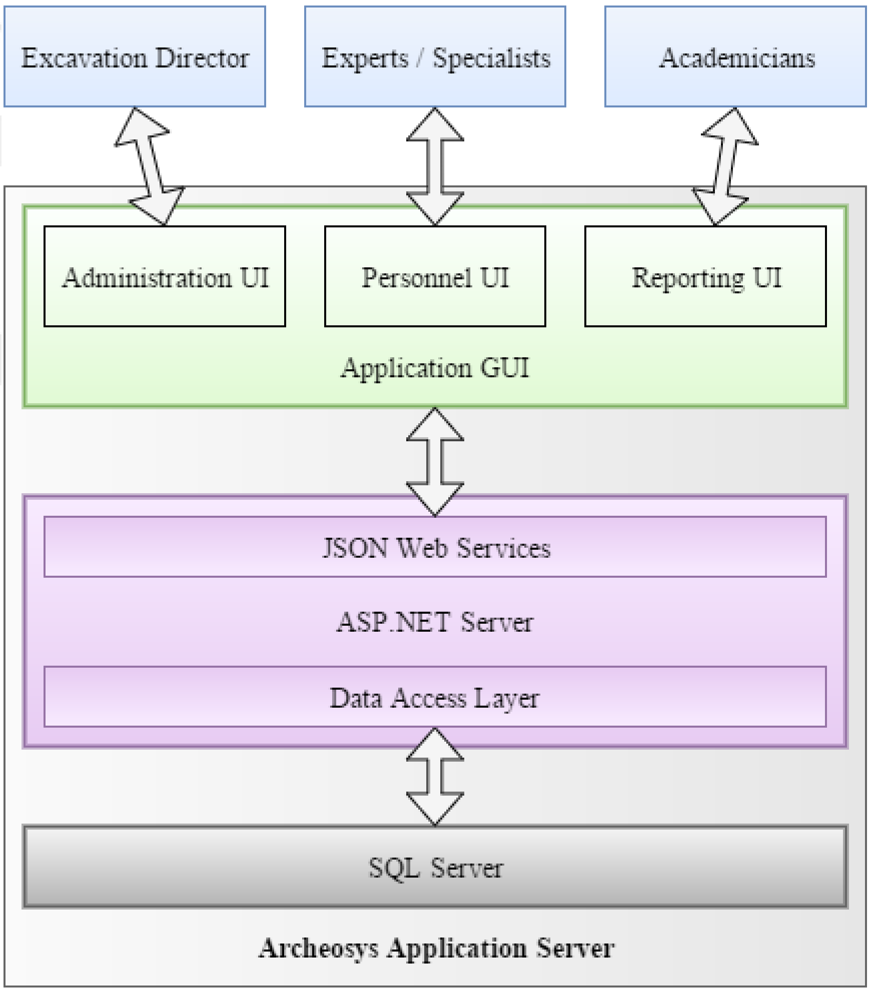


Figure 4.2 Block diagram of Archaeosys system.

There are three different authentication types. Excavation director can administer the whole system, experts log on to their stations and academicians connect to searching and reporting services. After logging into system, client server communication is carried on through Ajax (Asynchronous JavaScript and XML) calls and JSON (JavaScript Object Notation) web services. Ajax is preferred over ASP.NET PostBack and UpdatePanel. A comparison of Ajax, ASP.NET UpdatePanel and ASP.NET PostBack is displayed in Table 4.2.

Table 4.2 Comparison of client server communication alternatives. 1 notes the best, 2 notes the second best and 3 notes the worst (Ward, 2008).

	Ajax	**ASP.NET UpdatePanel**	**ASP.NET PostBack**
Speed	1	2	3
Lightweight	1	2	3
Easy Coding	3	2	1
Avoid Page Refresh	✓	✓	✗

When compared to ASP.NET UpdatePanel and PostBack, Ajax is faster, lighter for the system and has a more modern feel since it does not cause the web browser’s page refreshing or flickering. But since its response must be handled by the coder, it requires much more coding effort when compared to automated ASP.NET features.

ASP.NET Server gets the posted Ajax request, processes it and returns the output in JSON format. This component represents the business process layer (logic tier) of the application. This layer serves as an intermediary between database and GUI. Response format is selected to be in JSON form over XML. Since client side of the application is heavily JavaScript oriented, JSON can be processed easier. Json.NET framework is used for generating server response in JSON format. Json.NET can convert objects between .NET and JSON and it is faster than .NET's built-in JSON serializers. When combined with C# 4.0’s “dynamic” type, Json.NET can do powerful and easy JSON manipulation. Microsoft Developer Network states that the dynamic type is a static type, but an object of type dynamic turns static type checking off and it functions like it has type object (MSDN, n.d.). So, JavaScript objects sheltered in client side can easily and efficiently be represented and processed at server side, without creating representative C# classes.

ASP.NET Server is also responsible of generating case and Find receipts. Authorized users can download these receipts in Portable Document Format (PDF). For this task, ASP.NET Server uses wkhtmltopdf tool. wkhtmltopdf is open source and it renders HTML into PDF, but it cannot be directly included in a C# application. In order to benefit from powerful features of wkhtmltopdf, a .NET wrapper named TuesPechkin is imported to the application.

The last task of the ASP.NET Server is to connect to the SQL Server and request query execution. After getting the result from database server, ASP.NET Server processes the result and take necessary actions.

SQL Server hosts the database and runs queries over it. It also backs up the database in determined intervals. Authentication, personnel information, excavation related information and Finds' data are stored in SQL Server's database. Only alphanumeric characters are stored in database, whereas, all images are stored in file system. Only paths of images are stored in database. File system is chosen over SQL Server for storing images because: it is easier to code, it is lighter for SQL Server and it is cheaper.

4.2.2 System Decomposition

Archaeosys software can be decomposed functionally into three main components: administrator services, personnel services and academic services. General functional decomposition tree is shown in Figure 4.3.

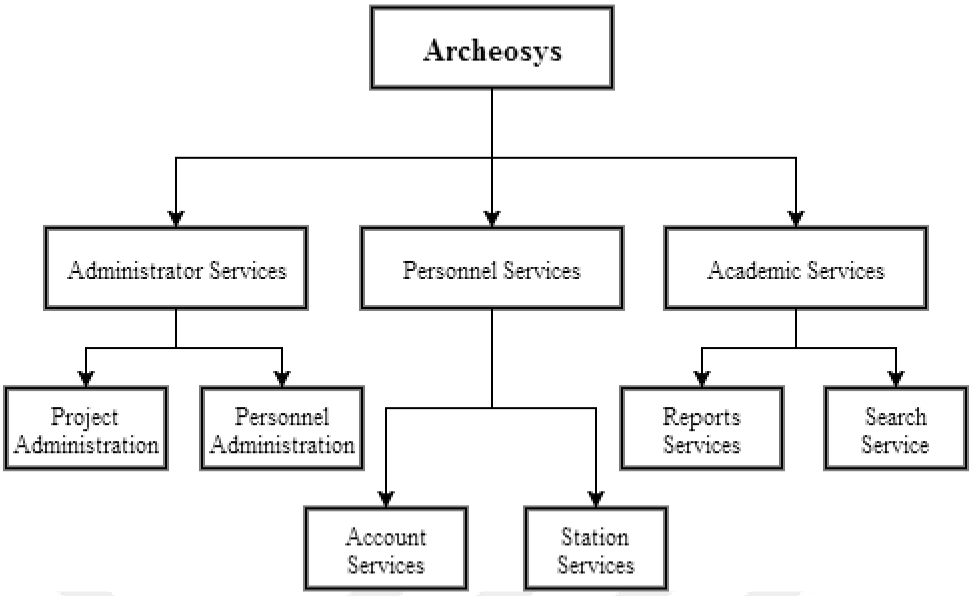


Figure 4.3 Archaeosys functional decomposition tree.

4.2.2.1 Administrator Services

Excavation director connects to administration services. As displayed in Figure 4.4, Administration services encapsulates project wise and personnel wise actions. These services are restricted only to excavation director.

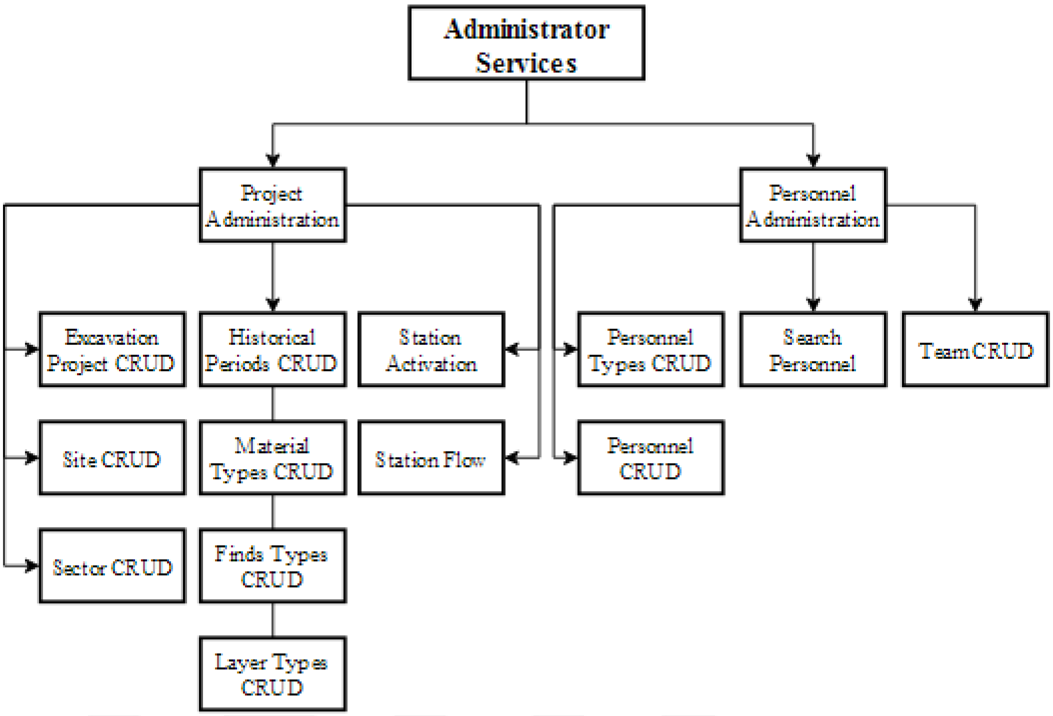


Figure 4.4 Administrator services functional decomposition tree.

Project administration task is functionally divided into three sub categories as follows:

- **Project Manipulation**

Excavation director (administrator) can **cr**eate, **u**pdate and **d**elete (CRUD) excavation projects. An excavation project is equivalent of a real life archaeological project. It can be a small scaled excavation or it can encapsulate several sites.

If created excavation project needs to have any site, administrator can create a single site or several sites for the project. Sites can be updated or deleted if they are mistakenly created.

In archaeological projects, depending on the complexity, sites can have a single sector or multiple sectors. Each sector can be updated or deleted if needed.

- **Excavation Parameters Management**

Excavation parameters are the variables that can change depending on the project. Instead of setting these parameters static, they are made controllable by administrator, so that he can set up the whole system as he wishes.

Historical periods are the possible values representing the excavated materials' era of creation. During the excavation, all excavated materials' historical periods are recorded by archaeologists.

Material types represent the material properties of excavated material. Finds can be made of bones, metal, glass, ceramics etc.

Finds types are the kinds of excavated material. They may be cooking pots, vases, figures, tools and so on.

Layer types are the properties of layer (strata) which the Find was found. Some examples of layer types are pebbly, grainy and chalky.

- **Station Management**

Stations within an archaeologic project can be configured by administrator. All possible types of stations are implemented in Archaeosys application. A station can be turned on or off for any project. This functionality provides a semi-dynamic structure for station management.

During the excavation process, after dug out, Finds need to travel several stations for different operations until they finally reach to warehouse. This routing between all stations can be configured by administrator.

Personnel administration is the second comprehensive functionality of administrator services. Personnel administration task can be functionally divided into three sub categories as follows:

- **Personnel Depicting**

  Administrator can create, update and delete personnel types for desired projects. Personnel types represent the duties of excavation crew. Some examples are excavation supervisor, worker, student, restoration expert etc. Administrator can also insert, update and delete personnel for any project. Personnel's type and scope of authority can be defined at the time of insertion or can be updated later.

- **Recorded Personnel Search**

  As the project gets larger and time goes by, the number of registered personnel may highly increase. Searching functionality for previously personnel gets important in this case. This functionality also has quick action such as freezing and unfreezing a personnel's account.

- **Team Management**

  For large scale projects, teaming up a group of personnel can be advantageous. Instead of assigning scope of authorities for every personnel one by one, creating a team and setting up its scope of authority is much easier and rational.

  With this functionality, administrator can create, update and delete teams. A team may consist of several personnel according to demands of administrator. Also the teams authority rules can be created, updated and deleted when needed.

4.2.2.2 Personnel Services

Personnel services are designed for station specialists and have restricted access only for them. Personnel services, as shown in Figure 4.5, can be divided into two major branches according to their functionalities, namely, account services and station services.

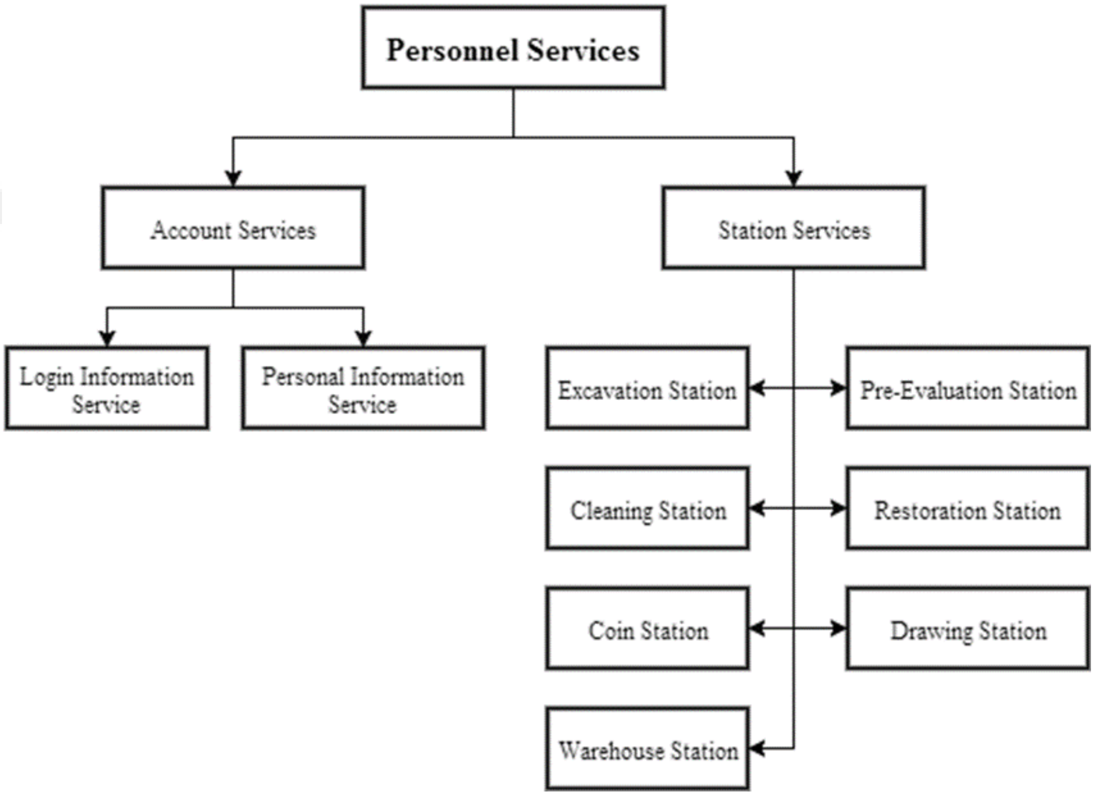


Figure 4.5 Functional decomposition tree of personnel services.

First major branch, account services, is broken down into two functional structure as follows:

- **Login Information Service**

  Simply put, this is the service for updating personnel's login credentials. As administrator initially creates personnel accounts and assigns default passwords, personnel can later change their passwords by this functionality. In case of forgetting, personnel can also reset their password with this service.

- **Personal Information Service**

  By using this service, personnel can update their personal information such as phone numbers, institute or address.

The other major branch, station services, contains the most important parts of Archaeosys system. Experts and specialists alter the state of Finds within the stations and record the process of their work with station services. At highest level, station services can be broken down into two functional parts as follows:

- **Operational Stations**

  Excavation station, cleaning station, pre-evaluation station, restoration station, drawing station and coin station are in this group. These are the stations where archaeological data is accumulated and stored. According to their scope of authority, archaeologists and experts connect to their station after logging into system. Within each station, they do their work, record their findings and transfer the archaeological material to appropriate stations.

- **Warehouse Station**

  Warehouse station is the last stop for archaeological materials. Warehouse keeper logs into this station and records the arrived items' warehouse data with this functionality. Detailed description of artifacts' location in warehouse must be recorded precisely.

4.2.2.3 Academic Services

Academic services are related to post analysis process of the archaeological excavation. With academic services' functionality, scientists can extract detailed information from the information stored in system for their scientific works. Functional decomposition of academic services can be seen in Figure 4.6.

Figure 4.6 Functional decomposition tree of academic services.

Academic services can functionally be divided into two primary branches as follows:

- **Report Services**

Report services provide the functionality of generating charts and textual reports. When compared to textual reports, charts are easier to read and extract analytical information. But in case of getting more detailed information, textual reports are more accurate.

- **Search Services**

If scientists are looking for Finds with specific attributes or sets of information, they can use this service. Search service provides a detailed search among all recorded attributes of processed Finds.

4.2.3 Database and Data Structures Design

Archaeosys is basically a database application. Storing, deleting and retrieving archaeological data comprises the largest part of its activities. Conceiving this aspect of the application, it can be concluded that an effective database design and building data structures with respect to designed database yields to success for development and maintenance processes of Archaeosys.

4.2.3.1 Database Design

Analyzing the nature of Smyrna Ancient City Excavation, it is concluded that there are two major branches of tasks to be implemented on system’s database. The first branch encompasses project’s administrational tasks. Defining the project, site, sector and archaeological parameters and personnel administration operations are in this branch. Second branch, archaeological activities, includes the station actions in which Finds are excavated, processed, recorded and stored, and also academic activities such as performing searches and getting reports. Administrational and archaeological activities not only differ in conceptual sense but also in work load. While administrational activities are mostly performed before starting the excavation, archaeological activities are performed during the excavation process. Archaeological activities also occupy more data space since they are performed more frequently than administrational activities.

Archaeosys software’s database is designed with SAP Sybase PowerDesigner. SAP Sybase PowerDesigner is a data modeling software which supports all architectural environments (Toolpark, 2013). Database tables and their relationships are visually prepared with SAP Sybase PowerDesigner and then exported to SQL Server for application development.

Archaeosys is not an open source software. Because of this, its database structure will not be displayed explicitly in this document. But, for clarification of its structure, an overview will be demonstrated with simple entity-relationship (ER) diagrams. For displaying cardinality relation between database tables, Crow's Foot Notation will be used.

As shown in Figure 4.7, an excavation project can have multiple sites, and each site can have multiple sectors. Also an excavation project must have one or more types of Finds, materials, layers (strata), and historical periods.

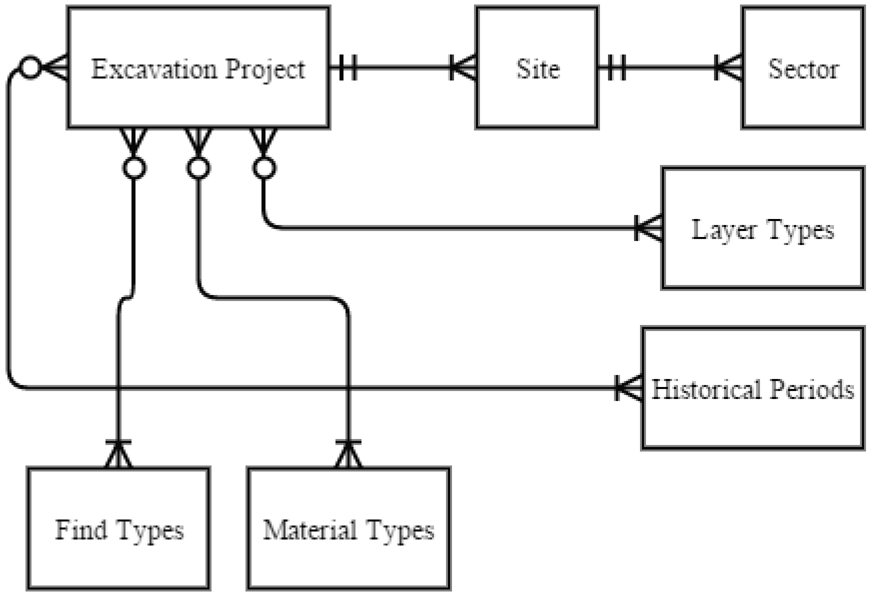


Figure 4.7 Excavation project ER diagram.

As shown in Figure 4.8 (A), each station has operations and actions to be executed on Finds. These operations are stored in Station Operation table. Some operations and statuses for cleaning station are "waiting for cleaning", "cleaning process started", "cleaning process ended".

As can be seen in Figure 4.8 (B), each excavation project has at least one station. Stations which are enabled within a project are called active stations. Depending on project, stations can be made active or passive by administrator.

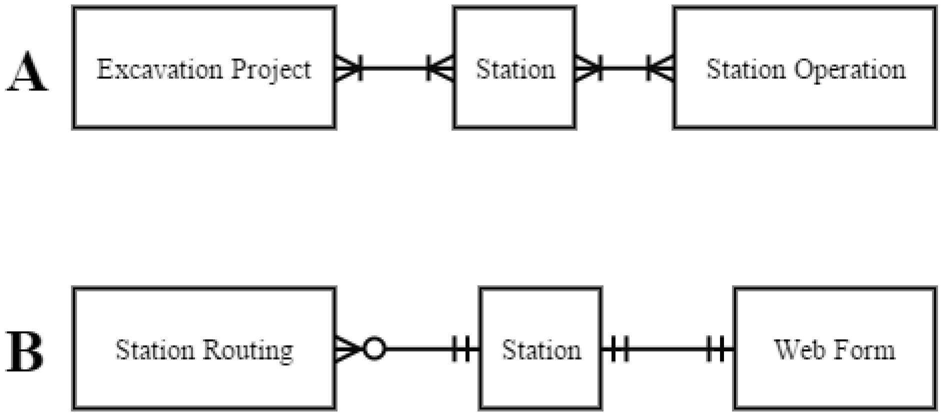


Figure 4.8 Station, excavation project and station operatin relation (A), and station, station routing, web form relation (B) ER diagram.

Stations are routed to each other for being able to transfer Finds in between. Also each station is represented by a web form. Station’s activities are performed at station’s web form. Each station must have only one web form.

As shown in Figure 4.9, each personnel must have credentials for logging into system.

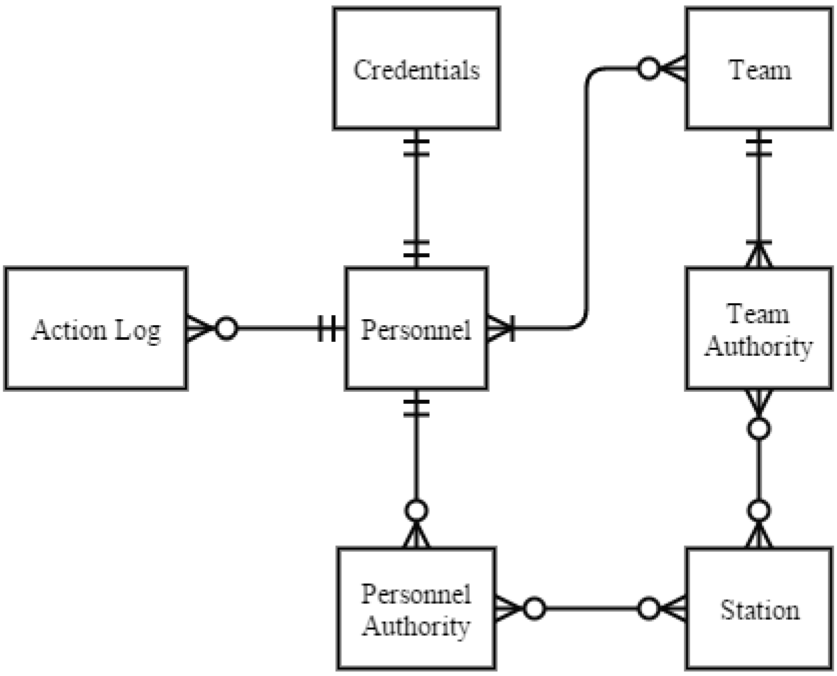


Figure 4.9 Personnel ER diagram.

Personnel authority table contains personnel's station access rights. Also, a personnel might be a member of zero or more teams and thus, can access to stations which his team has access to. After connecting to stations, all activities of personnel are stored in action log table.

Cases' relationships with other entities are shown in Figure 4.10. A case is a container for Finds which are discovered within a plan-square. At the time of creation, a case is labeled with a sticker which contains the name of the archaeologist who prepared and filled the case, the plan-square code in which the Finds were discovered, the date of creation, and inventory no which serves as case's identification number.

A case might have several photographs. Photographs are not directly stored in database. Photo table only contains the file system paths of photos. A case also might have several strata types for defining found items' strata.

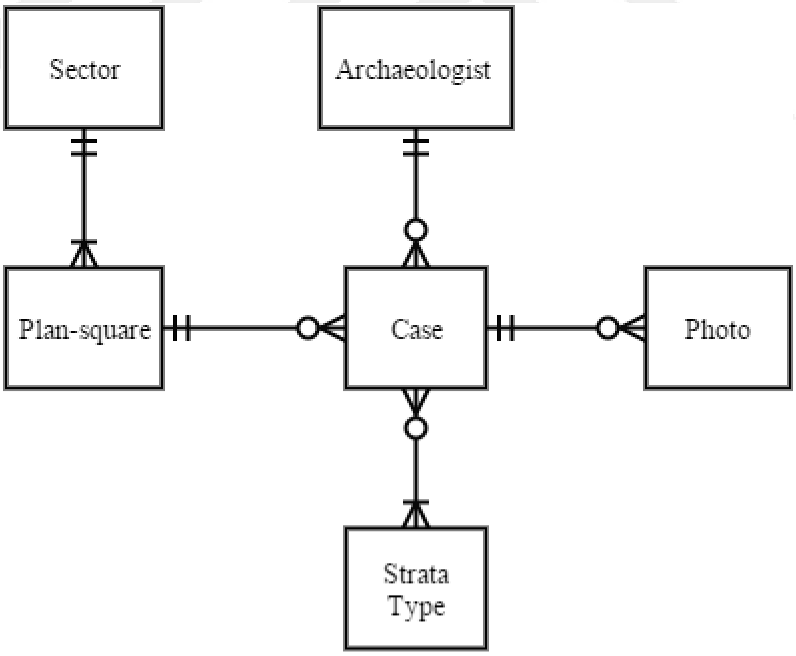


Figure 4.10 ER diagram for case entity.

Relationship of bags with other entities can be seen in Figure 4.11. Bag is the smallest global container in Archaeosys system. In Smyrna Ancient City Excavation, plastic zipper bags are used to keep Finds. At stations, Finds are taken from cases and after processing, they are placed inside bags. Bags have stickers which contain the case number from which the Finds are taken and a new identification number. Finds taken from one case may be placed into several different bags, if found necessary. Archaeosys software's database system is based on bags and every bag has an order number as an attribute. Finds within the case, which are not located inside any bag, are placed in a virtual bag with zeroth order by the system.

While being processed at a station, experts may need to separate some contents of a bag into a new bag. This newly created bag is named as the child of the original bag. For sake of logging every action taken at stations, this parent and child bag relationship is stored in database as a bag ancestor entity.

Bag location table keeps the last recorded location information for bags. At any time, administrator can see where a bag is from the system. And also experts are notified with the information of incoming bags to their stations.

A bag must have at least one piece of archaeological content. Bags contents are defined with their material types, functionalities and historical periods they belong to.

Coins are treated differently because they need a different kind of expertise to be examined. In Smyrna Ancient City Excavation, coins are placed in paper envelopes. This coin-envelope system is implemented in Archaeosys database. Coins from a single bag may get into multiple different envelopes according to their archaeological properties. Each envelope has data attributes related to its contents. System also stores every single coin's individual details.

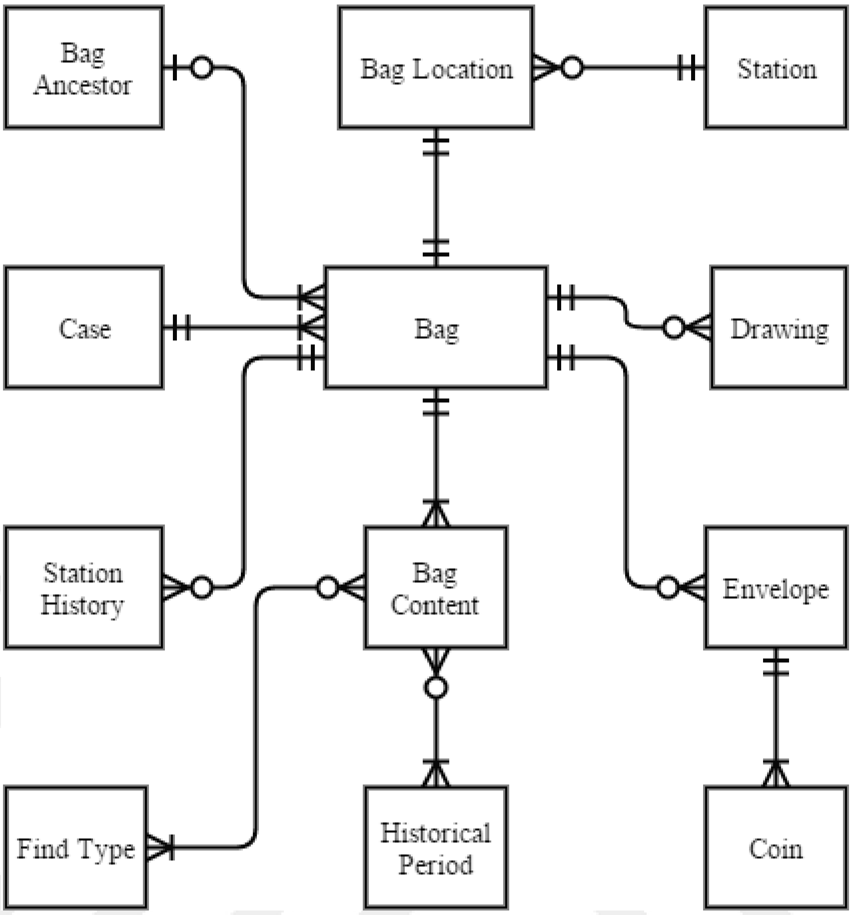


Figure 4.11 Bag ER diagram.

4.2.3.2 Design of Data Structures

Archaeosys software's logic tier, which lies in between data tier and presentation tier, briefly, is responsible for doing the necessary logical transformation between GUI and DB. In other words, logic tier forms a bridge between GUI and DB by mapping and processing requests and responses between these two. An archaeological entity's equivalent object may appear in GUI, logic tier or DB or it may appear in all of these layers.

As stated before, logic tier is developed in C# language, which allows creating custom data structures. A very powerful feature of C# is supporting both statically typed and dynamically typed variables. Static typing and dynamic typing have both advantages and disadvantages when compared with each other, but within a uniting development environment, they can be very beneficial for the programmer.

Well defined data structures (statically typed) are better for increasing code reusability. If instances of a data structure will be used frequently, it is better to make it well defined. For example, within the application, there are several asynchronous file uploaders in different web forms. By using asynchronous file uploaders, experts can upload case, bag and Find photographs and see the uploaded file instantly without waiting for the page refreshing. Asynchronous file uploader sends the chosen file asynchronously with an HTTP POST to the server. Server copies the file to file system and returns the response to the client asynchronously. If upload succeeds, server returns the file's path from file system, otherwise, server returns an error message with an error code. Server's response, then, is parsed into a JSON object and processed in client side. Data structure for server's image uploading result is shown in Figure 4.12.

```
[DataContract]
internal class ImageUploadResult
{
    [DataMember]
    // error code
    internal int e { get; set; }
    [DataMember]
    // error message
    internal string m { get; set; }
    [DataMember]
    // file path as result
    internal string r { get; set; }
}
```

Figure 4.12 ImageUploadResult data structure.

Server's response is a serialized instance of ImageUploadResult class. In client side, this response is parsed and processed as shown in Figure 4.13.

```
var data = $.parseJSON(serverResponse);

if (data.e) {
    // we got an error
    handleError(data.m);
}
else {
    // display uploaded image
    addDrawing(data.r);
}
```

Figure 4.13 JavaScript code snippet for client side response handling.

Other well defined data structures and processing mechanisms for these data structures are very similar to the ones explained above. It is not found necessary to explain all of them, but put in a nutshell, their names will be given as: BagObject, CaseObject, PersonnelObject and ValueTextObject.

Dynamically typed objects constitute the other section of data structures. If there is no necessity to use instances of a data structure frequently, or a data structure encapsulates complex fields such as arrays of complex objects, it is easier to create data structures on the fly. Creating an object of dynamic type in C# is very similar to creating a JSON object in JavaScript. Operations of a C# object of type dynamic cannot be resolved in compile time, but its operations are resolved at runtime. A code snippet is shown in Figure 4.14.

```
// create a dynamic bag content object
dynamic bagContentObj = new JObject();

// set its keys and values
bagContentObj.id = id;
bagContentObj.objects = objects;
bagContentObj.quantity = quantity;
bagContentObj.periods = periods;
bagContentObj.details = details;

// send the object to client
return JSManager.JObjToString(bagContentObj);
```

Figure 4.14 An example usage of C# type, dynamic.

As shown in Figure 4.14, after creating an instance of type, dynamic, programmer is free to set its fields and assign their values just like creating a JSON object. Values can be mixed types or even nested dynamic objects.

Other dynamically created data structures are programmatically similar to example given in Figure 4.14. So, it is not found necessary to explain their structure again.

CHAPTER FIVE
USER INTERFACE AND FUNCTIONALITIES

As mentioned in chapter 4.1.2, Smyrna Ancient City Excavation Project's nature forced the necessity of developing an application which should be able to run on both computers and mobile devices. Responsive design approach and its frameworks were studied, and Twitter's Bootstrap was chosen for the application's front end development framework.

While designing and developing the user interface of Archaeosys software, several features such as being friendly to users and being able to work flawlessly on iOS, Android and Windows Phone devices were taken into consideration. Throughout the development process, layout and design of application's all pages (screens) are discussed with Smyrna Ancient City Excavation crew for achieving the best usability. Also all pages are tested on several types of mobile devices.

Application's user interface can be examined in four categories: application's home page, administrational pages, personnel pages and academic pages.

5.1 Application's Home Page

Application's home page is the first page to be visited by any user. From application's home page, users can view help page, change application's language and can visit login page. Login page is displayed in Figure 5.2 (B).

Captured images of application's home page and its mobile view are shown in Figure 5.1 and Figure 5.2 (A) respectively.

Figure 5.1 Application's home page, viewed from computer.

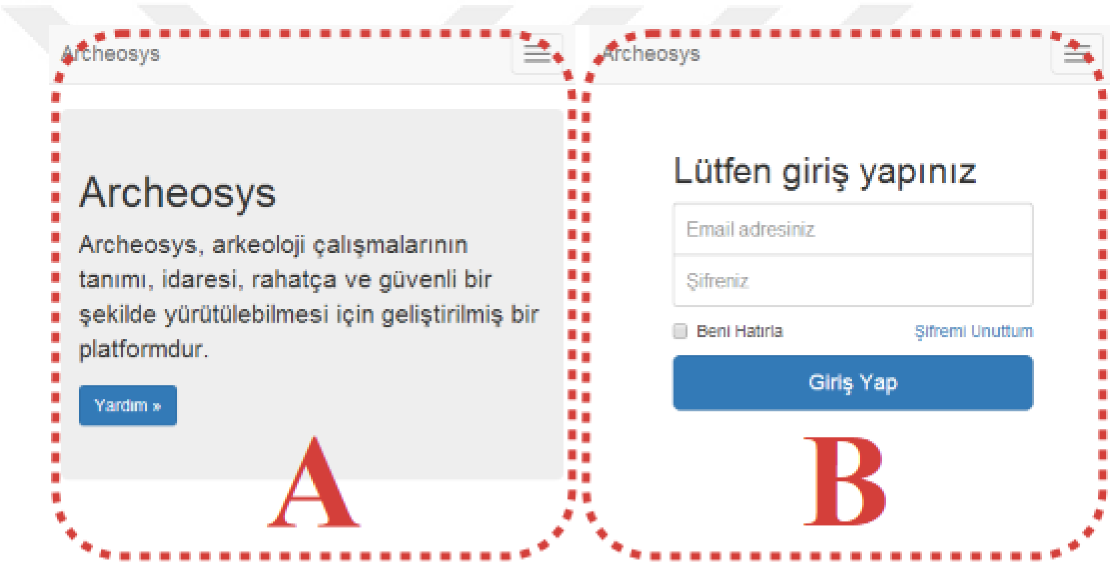


Figure 5.2 Application's home page (A), and login page (B), viewed from smart phone.

5.2 Administrational Pages

Administrator's home page is displayed in Figure 5.3 (A). There are two administrational menu items in this page, which are project administration and personnel administration. Their sub-menu items in expanded states are shown in Figure 5.3 (B) and Figure 5.3 (C) respectively.

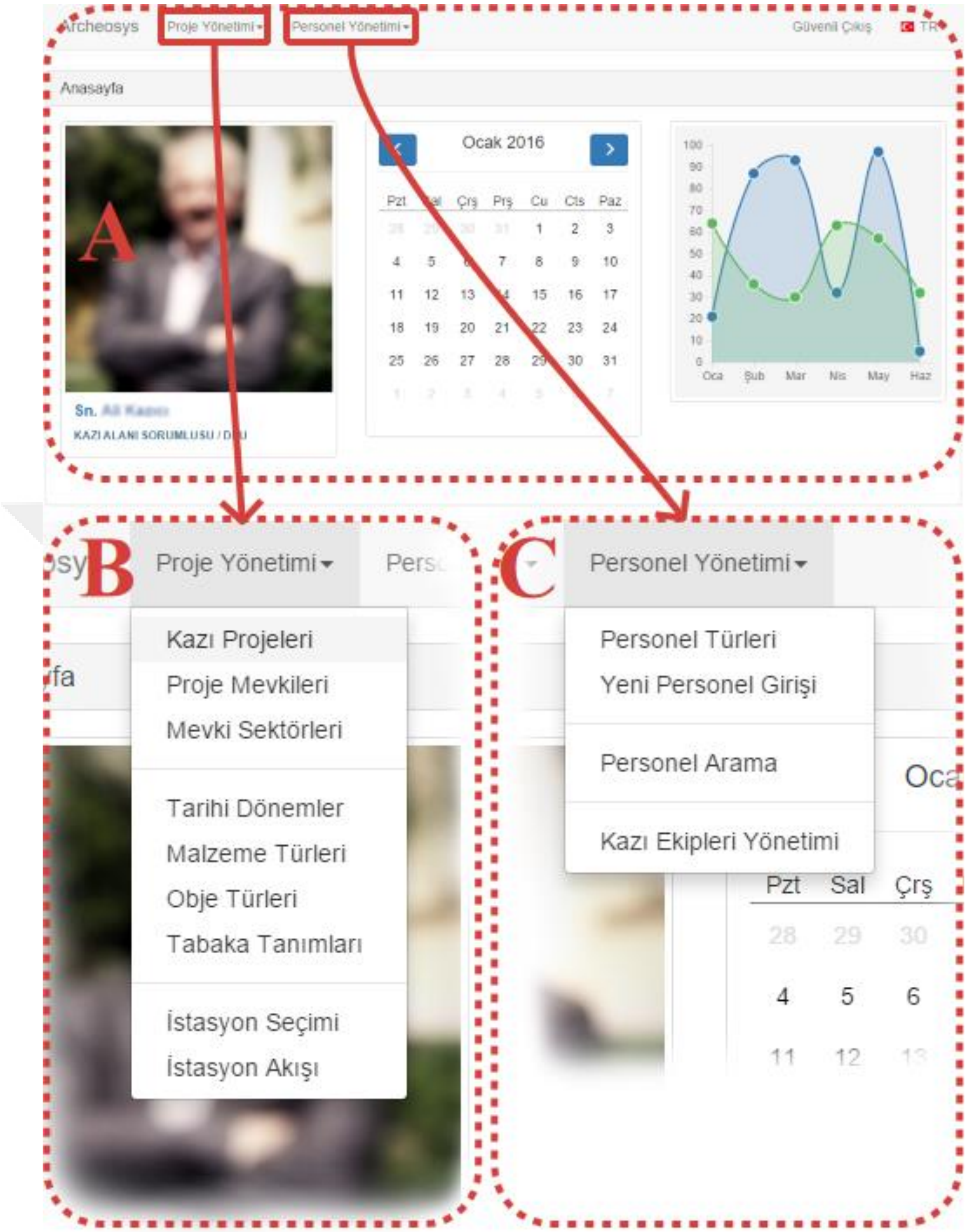


Figure 5.3 Administrator's home page (A), project administration menu (B), personnel administration menu (C), viewed from a tablet device.

As shown in Figure 5.3 (B), there are three groups of sub-menu items in project administration category. From top to bottom, these groups are organized as project manipulation, excavation parameters management and station administration.

Three groups of sub-menu items in personnel administration category can be seen in Figure 5.3 (C). From top to bottom, these groups are organized as personnel management, searching registered personnel and team management.

Since their functionalities are explained in section 4.2.2.1 and their functional decomposition is illustrated in Figure 4.4, all pages related to administrational sub-menu items will not be displayed in this document, but some images will be displayed for having an idea of what their visual designs look like.

The third sub-menu item from project manipulation category, which is “sector administration”, redirects the administrator to sector administration page. An image of sector administration page is displayed in Figure 5.4. In this page, administrator can create, update or delete sectors for desired archaeological sites.

The third sub-menu item from excavation parameters category is “Find types administration”. An image of Find types administration page is displayed in Figure 5.5. In this page, administrator can create, update or delete types of Finds for archaeological projects.

The second sub-menu item from station administration category, which is “station routing administration”, redirects the administrator to station routing administration page. An image of station routing administration page is displayed in Figure 5.6. In this page, administrator can manage the inter-stationary routing.

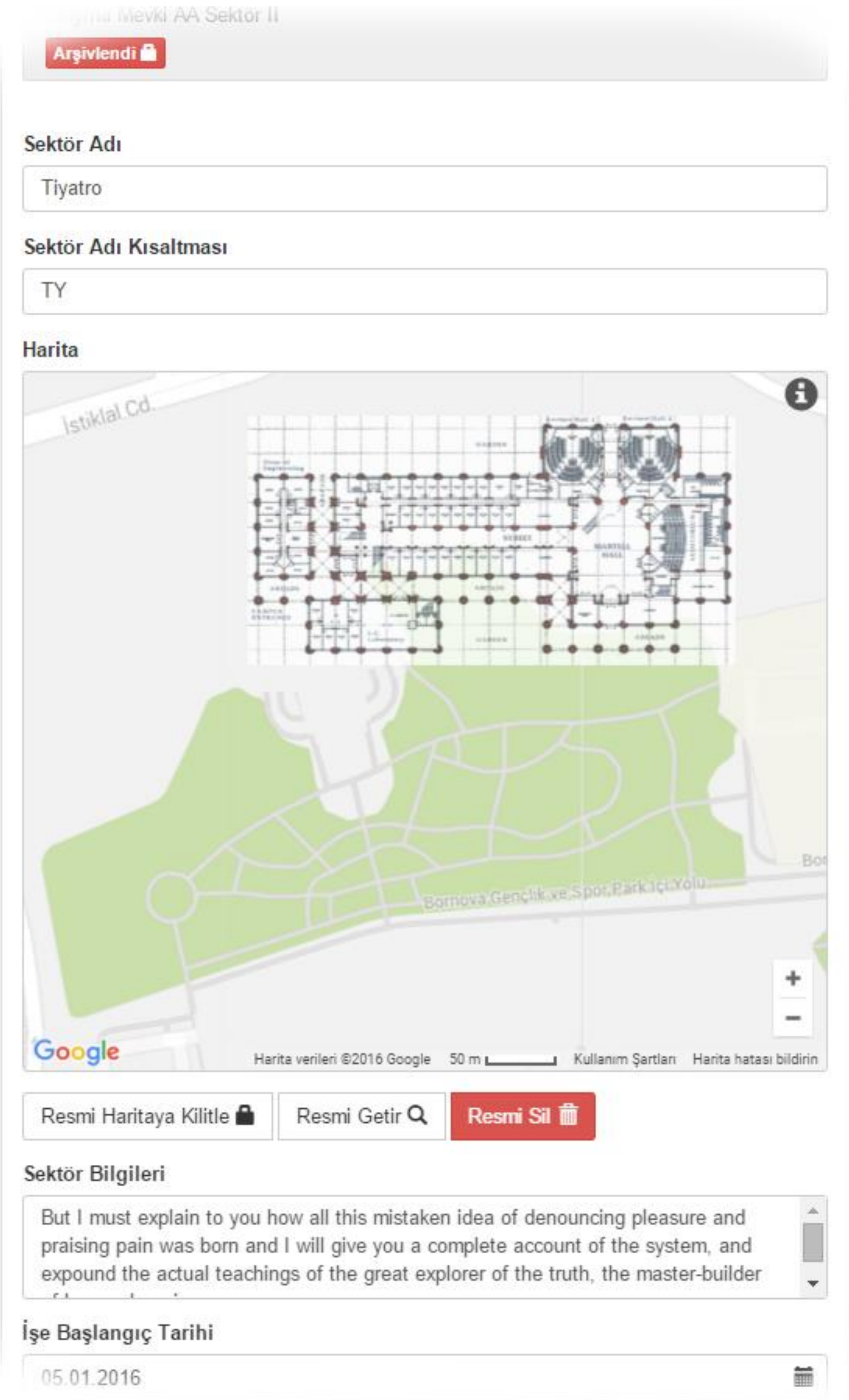


Figure 5.4 A section of sector administration page, mobile view.

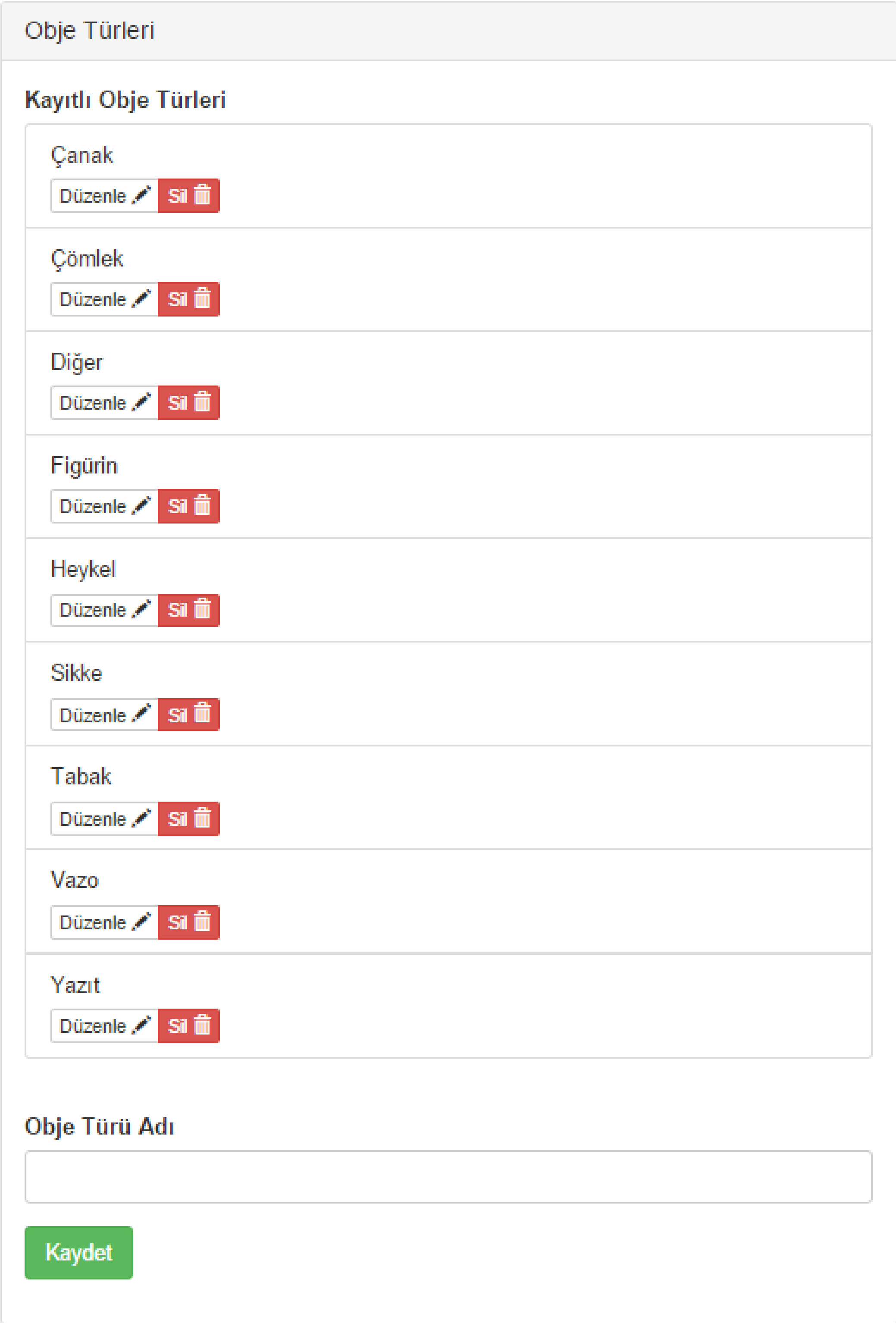


Figure 5.5 Find types administration page.

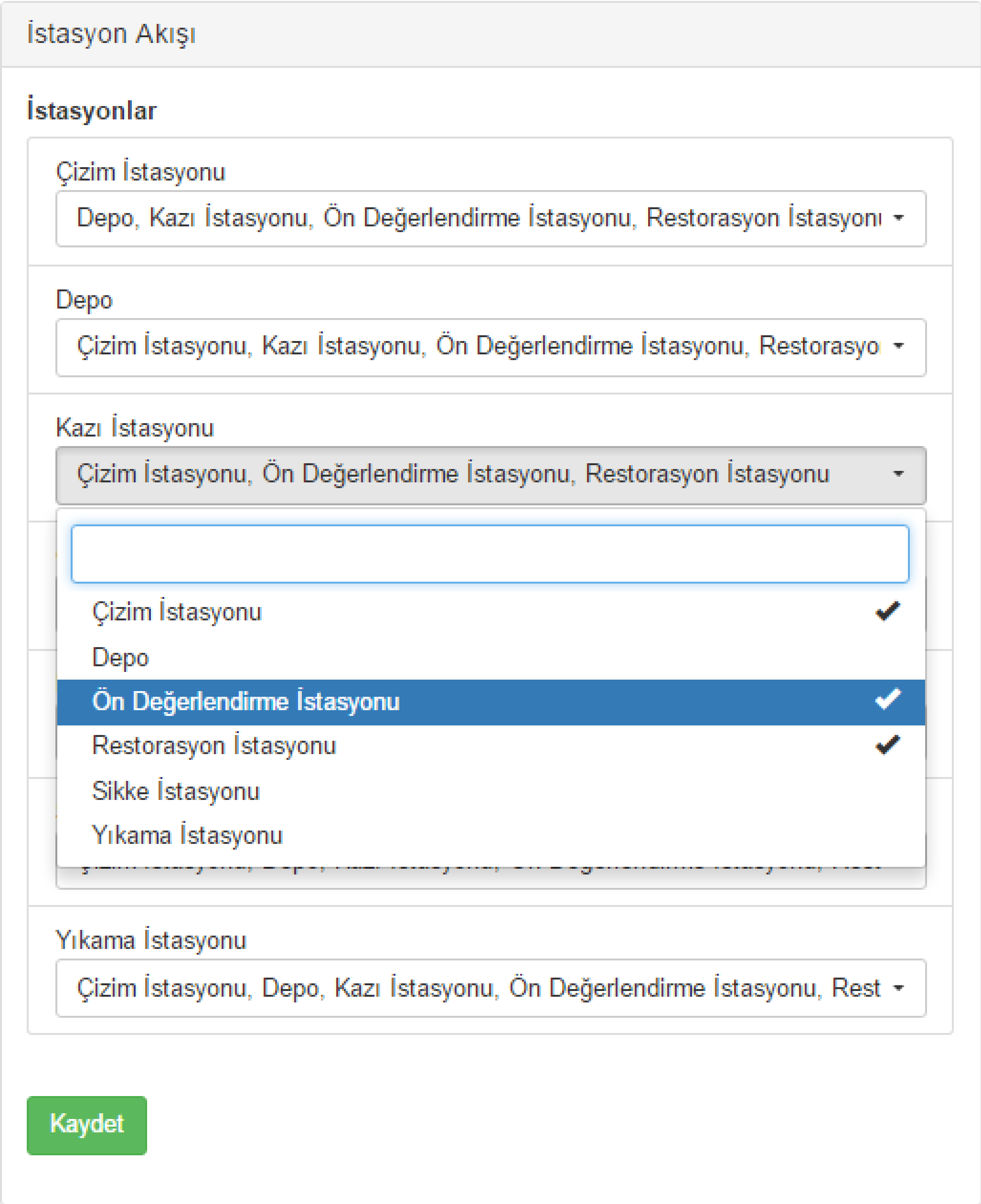


Figure 5.6 Station routing administration page in action.

The second sub-menu item from personnel administration category, which is "personnel registration", redirects the administrator to personnel registration page. In this page, administrator can register new personnel into the system by entering personal details, set their scope of authority within the system and create their initial login credentials. An image of personnel registration page is displayed in Figure 5.7.

The third sub-menu item from personnel administration menu, which is "personnel searching", redirects the administrator to a page where he can search and find any registered personnel. An image of personnel searching page is displayed in Figure 5.8. In this page, administrator can also freeze or update any personnel's account or delete a personnel from the system.

The last sub-menu item from personnel administration menu, which is "team management", redirects the administrator to team administration page. In this page, administrator can create, update or delete any team. In this page, administrator can also assign the teams' scopes of authorities. Team management page is partially displayed in Figure 5.9.

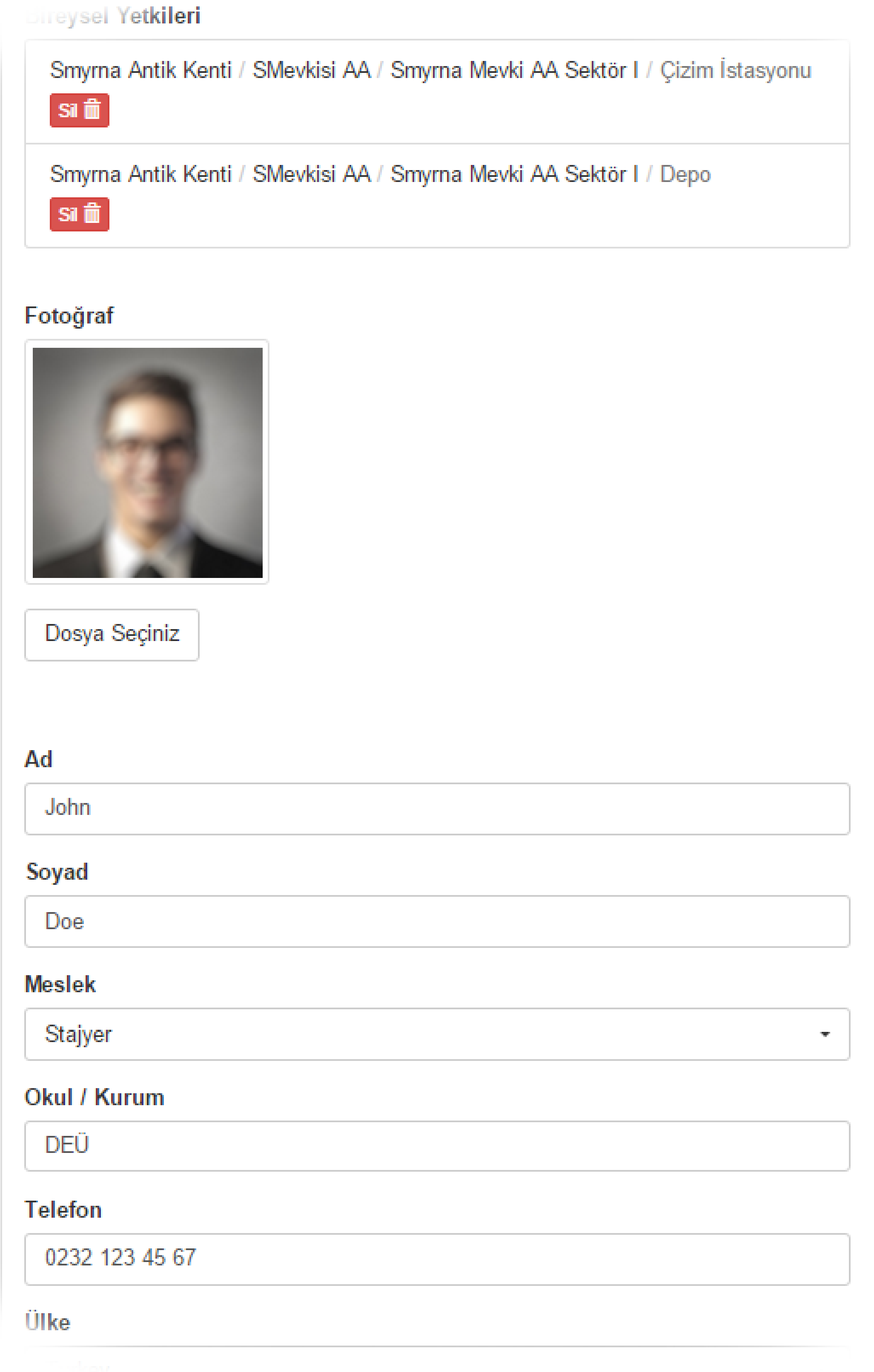


Figure 5.7 A section of personnel registration page, mobile view.

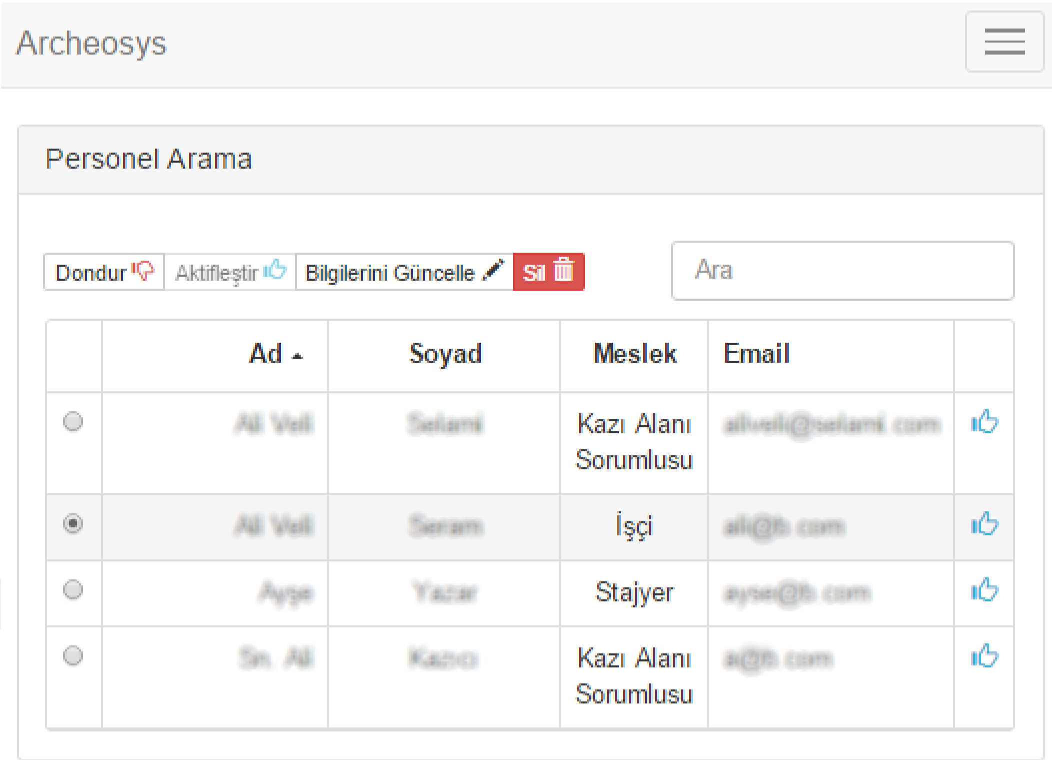


Figure 5.8 Personnel searching page, mobile view.

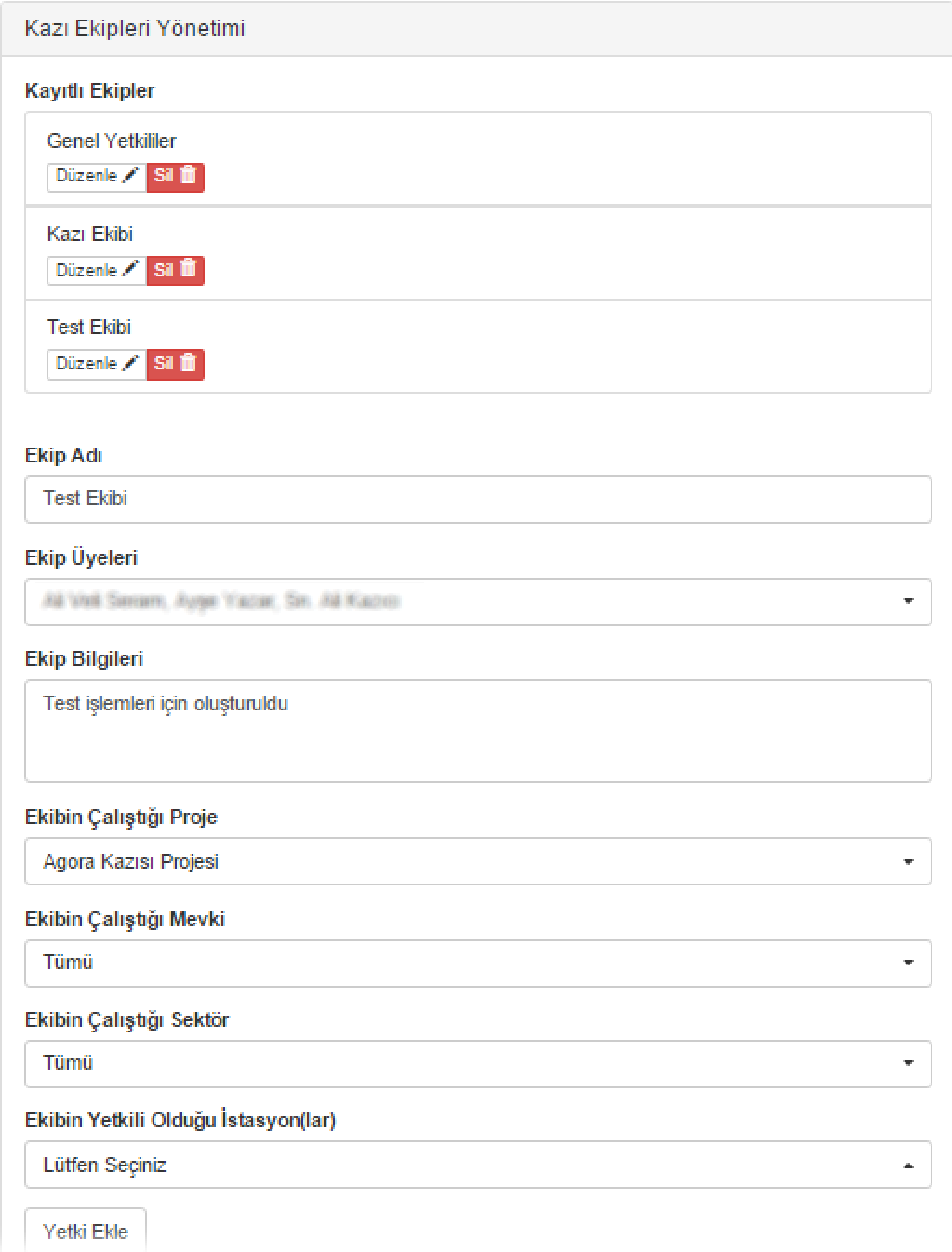


Figure 5.9 A section of team administration page.

5.3 Personnel Pages

Personnel can access their home pages after logging into system. According to their authority, they can pick the project, site and sector they are going to work from the dropdown menus shown in Figure 5.10 (A). According to personnel's project, site and sector selection, their authorized stations appear on screen as shown in Figure 5.10 (B). From this section, they can connect to their stations.

Excavation station is the first station to be examined. A mobile view of excavation station can be seen in Figure 5.11 and Figure 5.12. Excavation personnel can see their currently processed and past processed cases from the section shown in Figure 5.11 (A). Also, in this station, excavation personnel can see their "continuing" and "closed" cases from the section displayed in Figure 5.11 (B). During the excavation process, a case may be filled with Finds in a period which is longer than a day. In this case, the case being filled is labeled as "continuing" case. If a case is ready to be sent to cleaning station, it is labeled as "closed" case. Information fields for a new case creation can be seen in Figure 5.11 (C) and Figure 5.12. Also, from this page (excavation station), case's descriptive information can be exported in PDF format for labelling the case later with a sticker.

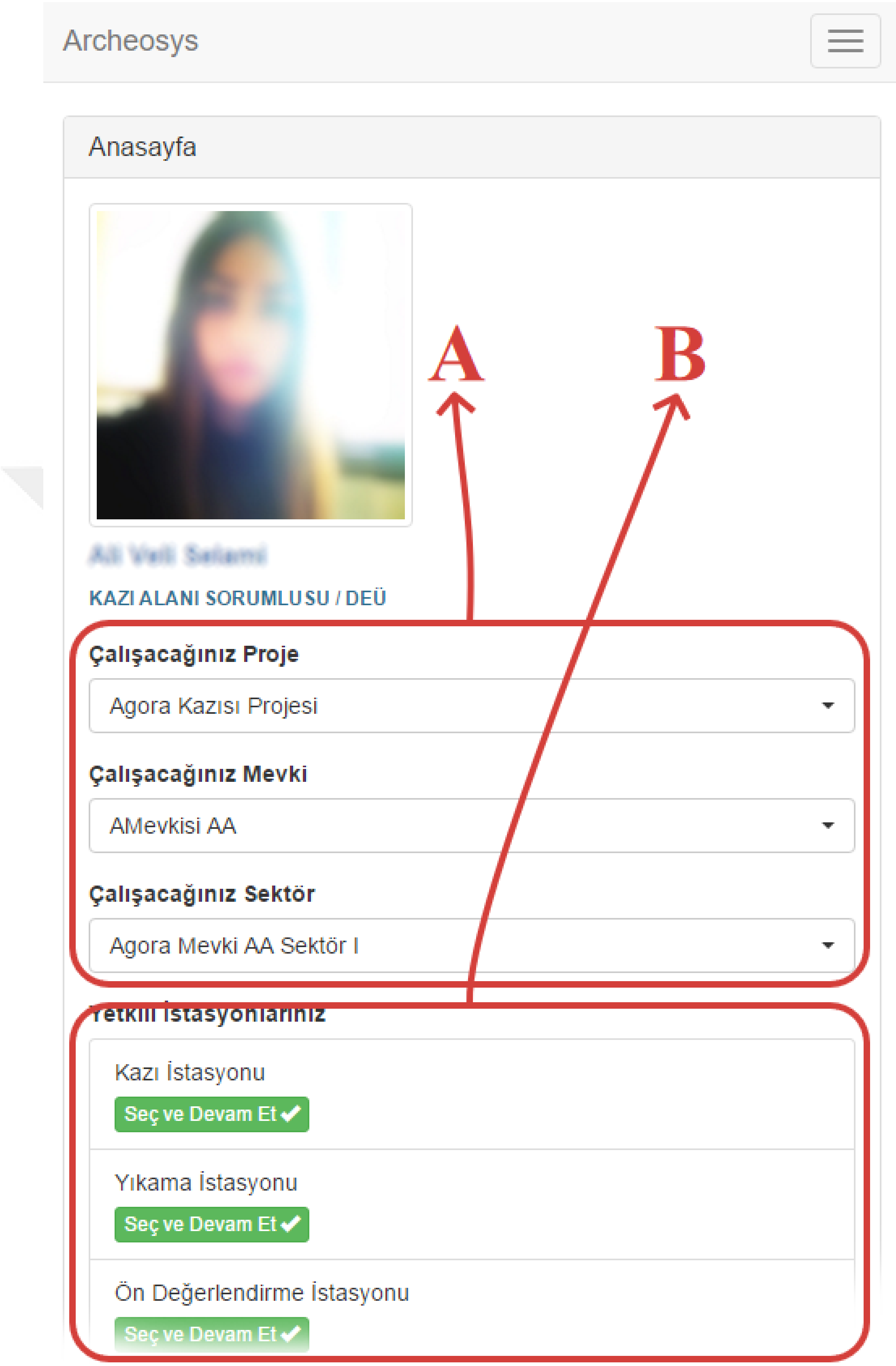


Figure 5.10 Personnel home page, mobile view.

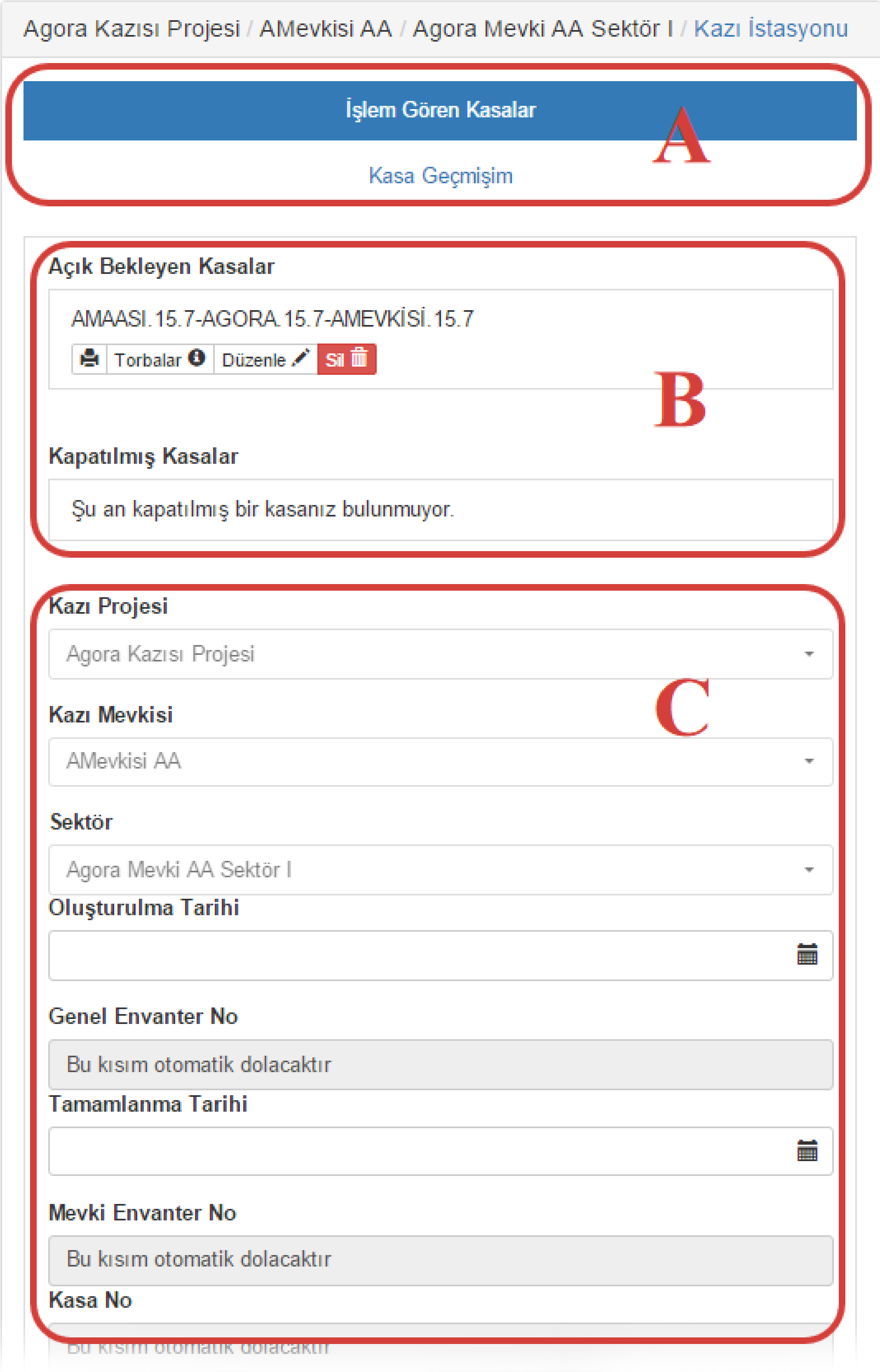


Figure 5.11 Excavation station part I, mobile view.

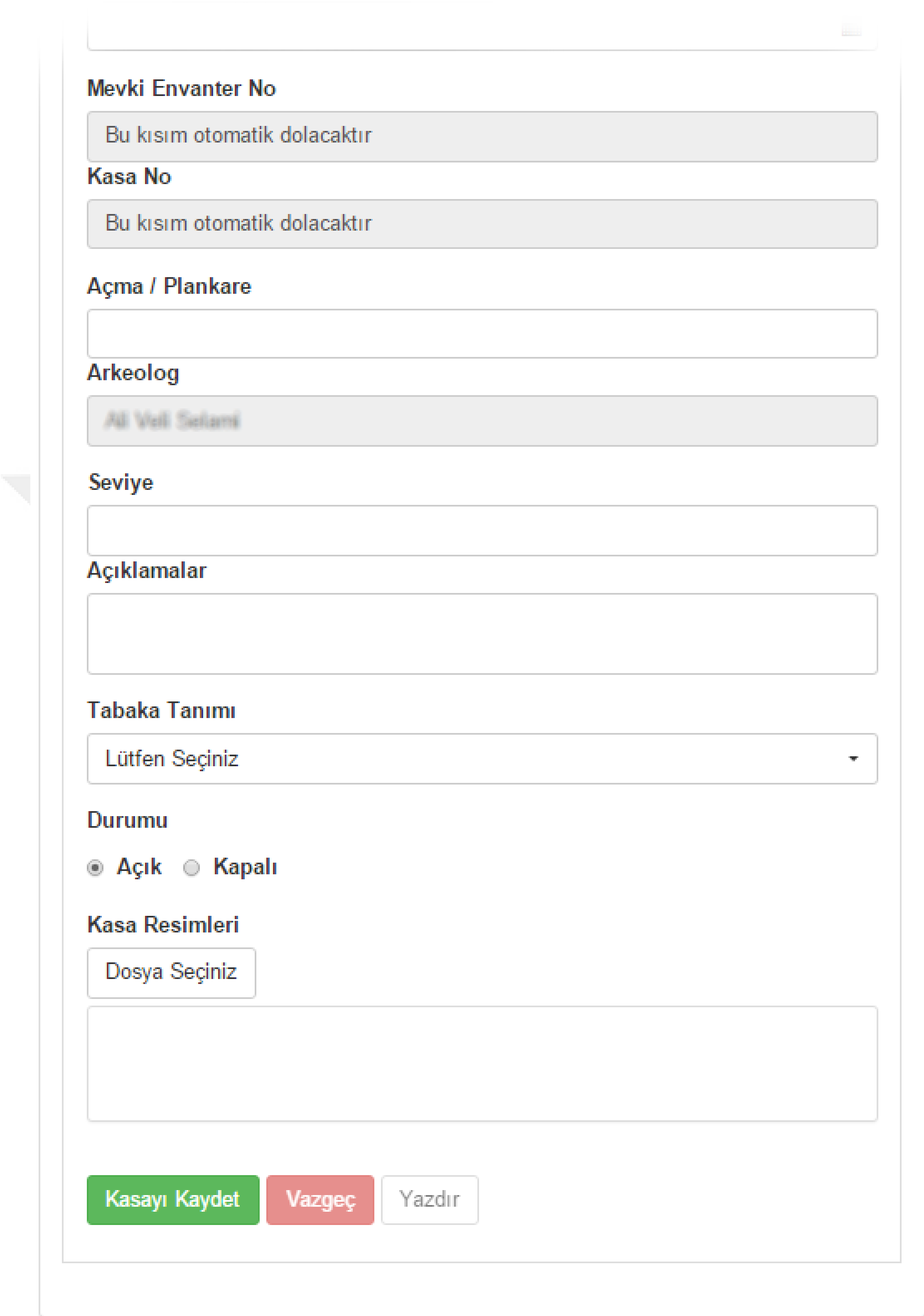


Figure 5.12 Excavation station part II.

User interface of cleaning station is displayed in Figure 5.13. The section where cleaning personnel can view their “currently processing”, “incoming” and “past processed” cases is shown in Figure 5.13 (A). Cases with “currently processing” labels are the cases which are at this station, being processed and waiting to be sent to other stations. The section of the station in where “currently processed” cases are listed can be seen in Figure 5.13 (B). Cases with “incoming” labels are the ones which are sent to cleaning station but not arrived yet. Cases with “past processed” labels are the cases which are already processed and sent to other stations.

Drop-down menu, which is shown in Figure 5.13 (C), contains the possible actions that can be taken in cleaning station. Upper part of the drop-down menu contains the statuses of cases being processed and the lower part of the drop-down menu contains the list of stations to which cases can be sent from cleaning station.

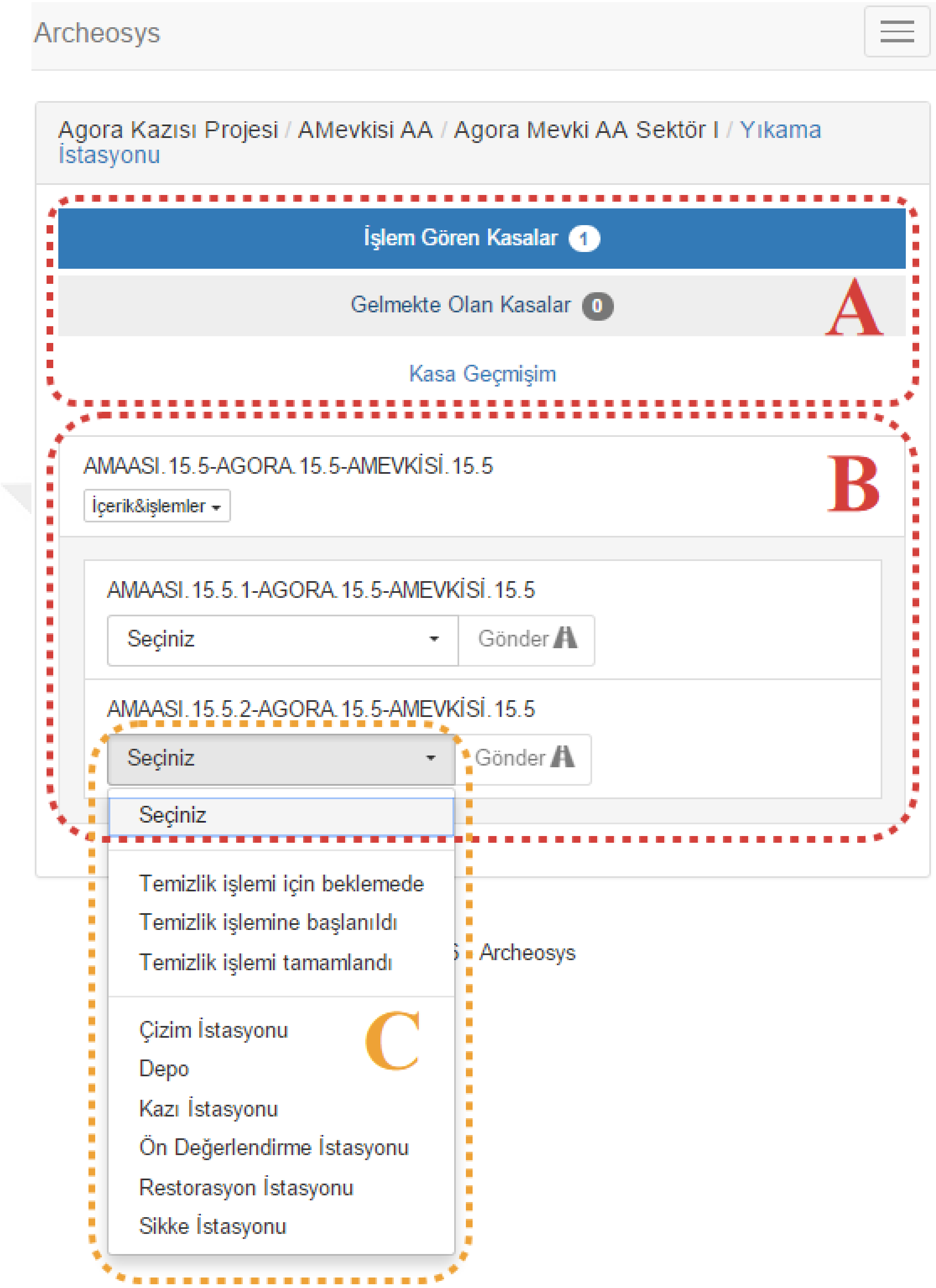


Figure 5.13 Cleaning station, mobile view.

User interface illustration of pre-evaluation station is distributed to Figure 5.14, Figure 5.15 and Figure 5.16.

The section of pre-evaluation page which allows switching between “currently processing”, “incoming” and “past processed” cases is displayed in Figure 5.14 (A). Active (“currently processing”) case and its child bags are shown in Figure 5.14 (B). Active (“currently processing”) bag of active (“currently processing”) case is marked with a pale blue background. Information entry fields related to active (“currently processing”) bag, which are to be filled by the pre-evaluation station’s personnel are shown in Figure 5.14 (C) and Figure 5.15 (A).

Input fields for adding Finds to active (“currently processing”) bag are shown in Figure 5.15 (B) and Figure 5.16 (A). By using these fields, pre-evaluation station personnel can add as many Finds as they want to active (“currently processing”) bag. List of added Finds to active (“currently processing”) bag is shown in Figure 5.16 (B). Finally, quantities of Finds in active (“currently processing”) bag according to their original historical periods are shown in Figure 5.16 (C).

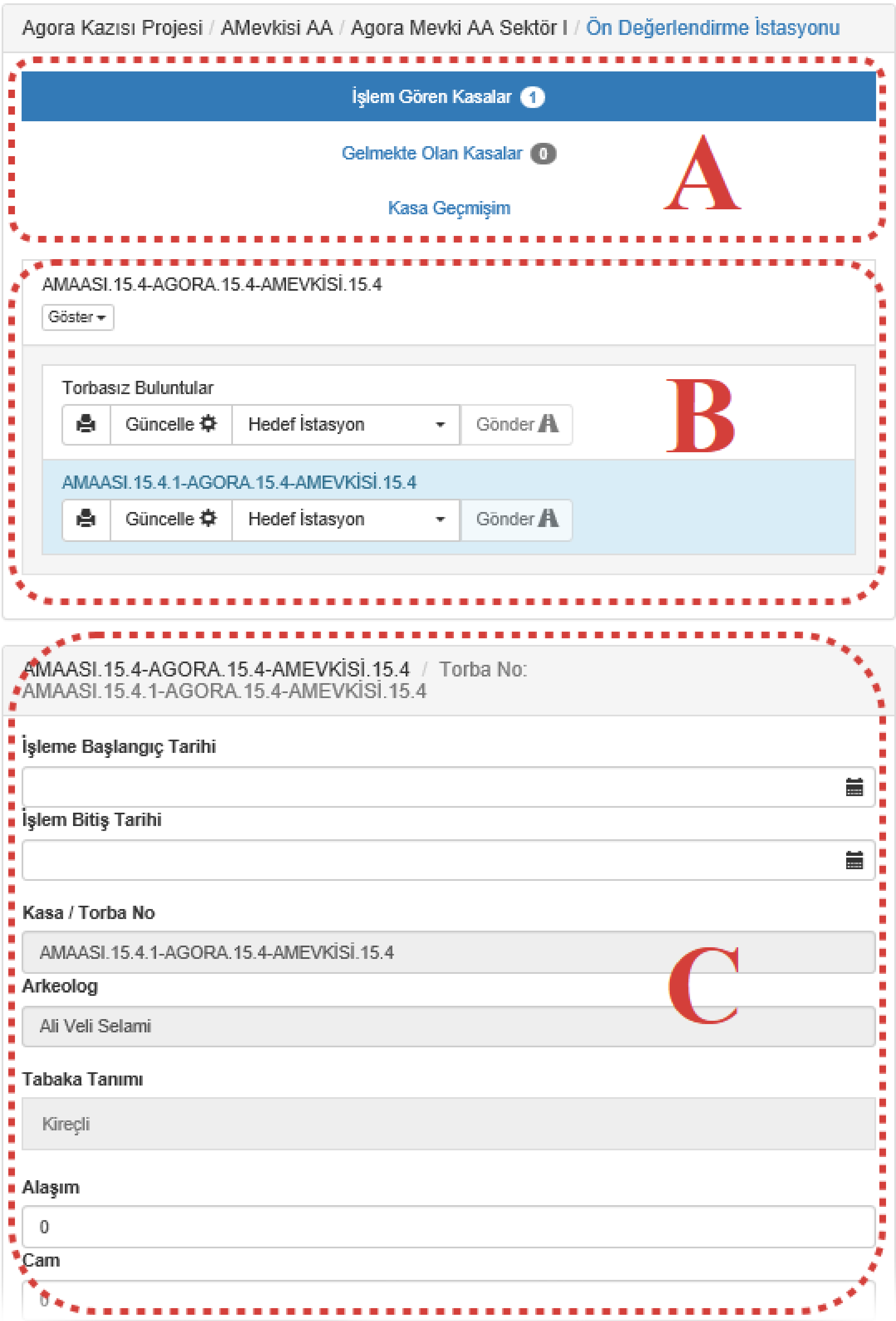


Figure 5.14 Pre-evaluation station part I.

Figure 5.15 Pre-evaluation station part II.

Figure 5.16 Pre-evaluation station part III.

User interface of drawing station can be seen in Figure 5.17. In Figure 5.17 (A), the section of drawing station's page, which allows switching between "currently processing", "incoming" and "past processed" cases, can be seen. Active ("currently processing") case and its child bags are shown in Figure 5.17 (B). The section, where station personnel can upload drawing files and images of processed Finds and enter details about their work, can be seen in Figure 5.17 (C).

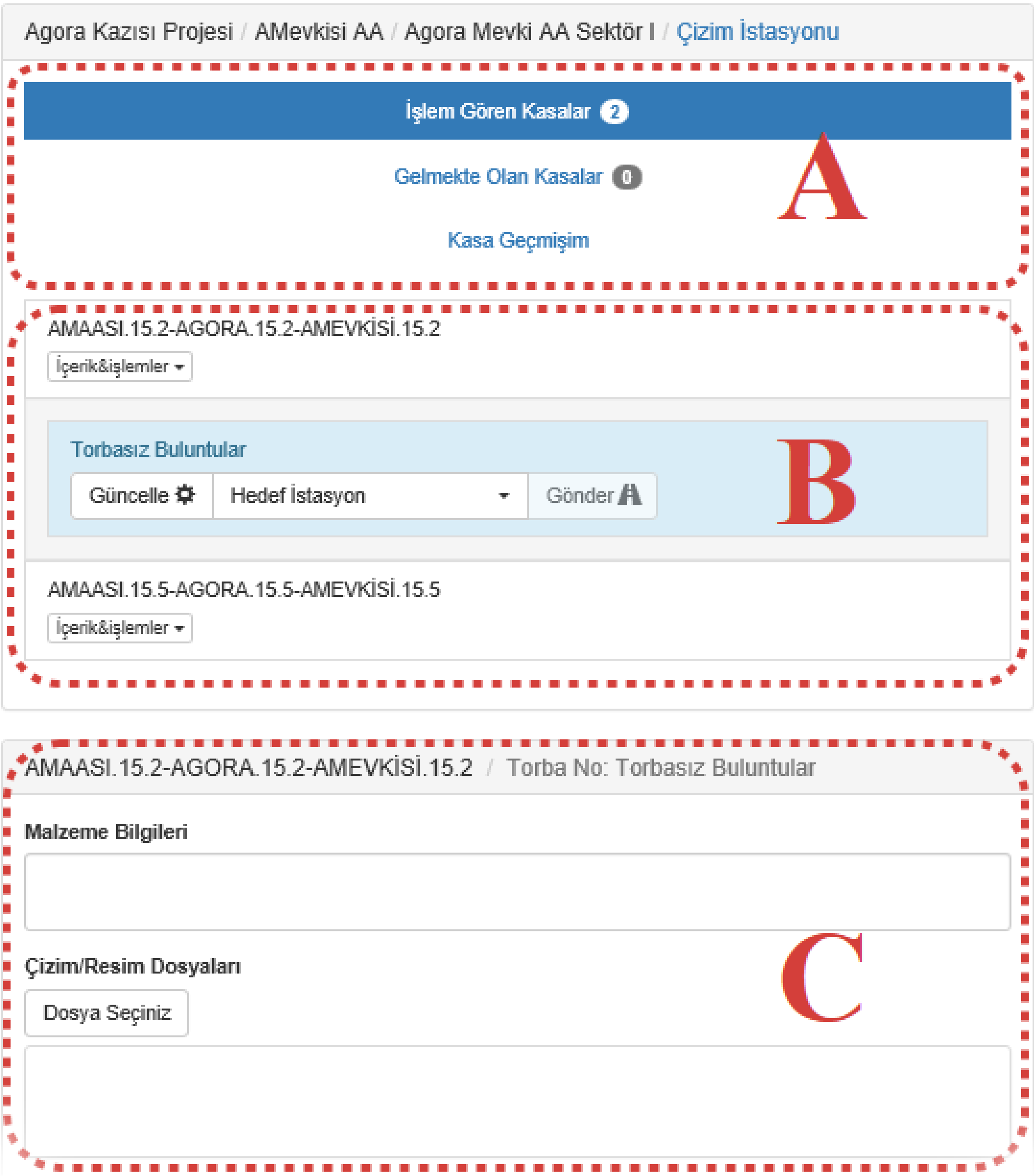


Figure 5.17 Drawing station, mobile view.

Coin station’s user interface is shown in Figure 5.18 and Figure 5.19. The section of coin station’s page which allows switching between “currently processing”, “incoming” and “past processed” cases is shown in Figure 5.18 (A). Active (“currently processing”) case and its child bags are shown in Figure 5.18 (B).

The section where coin related information can be entered is shown in Figure 5.18 (C). Recorded coins and their properties, listed as a table, can be seen in Figure 5.19 (A). From recorded coins table, a new coin envelope can be created which contains the selected coins displayed in the coin list. The section where recorded coin envelopes are listed is shown in Figure 5.19 (B). In Figure 5.19 (C), a modal window, from which coin envelopes can be created by entering envelope’s front face and back face information, can be seen. When coin station personnel exports a printable coin envelope file, this recorded information is shown on the faces of the envelope image.

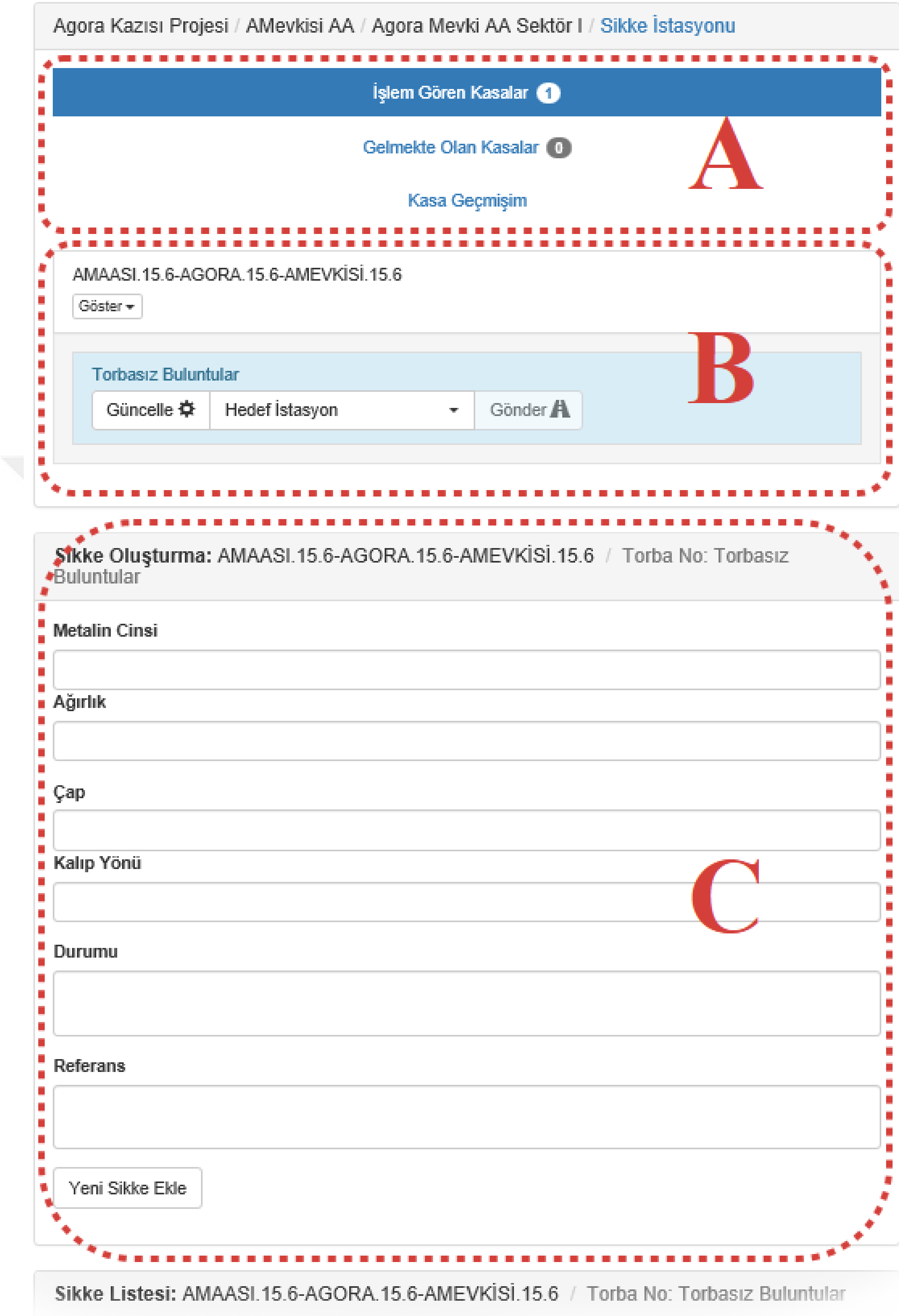


Figure 5.18 Coin station part I, mobile view.

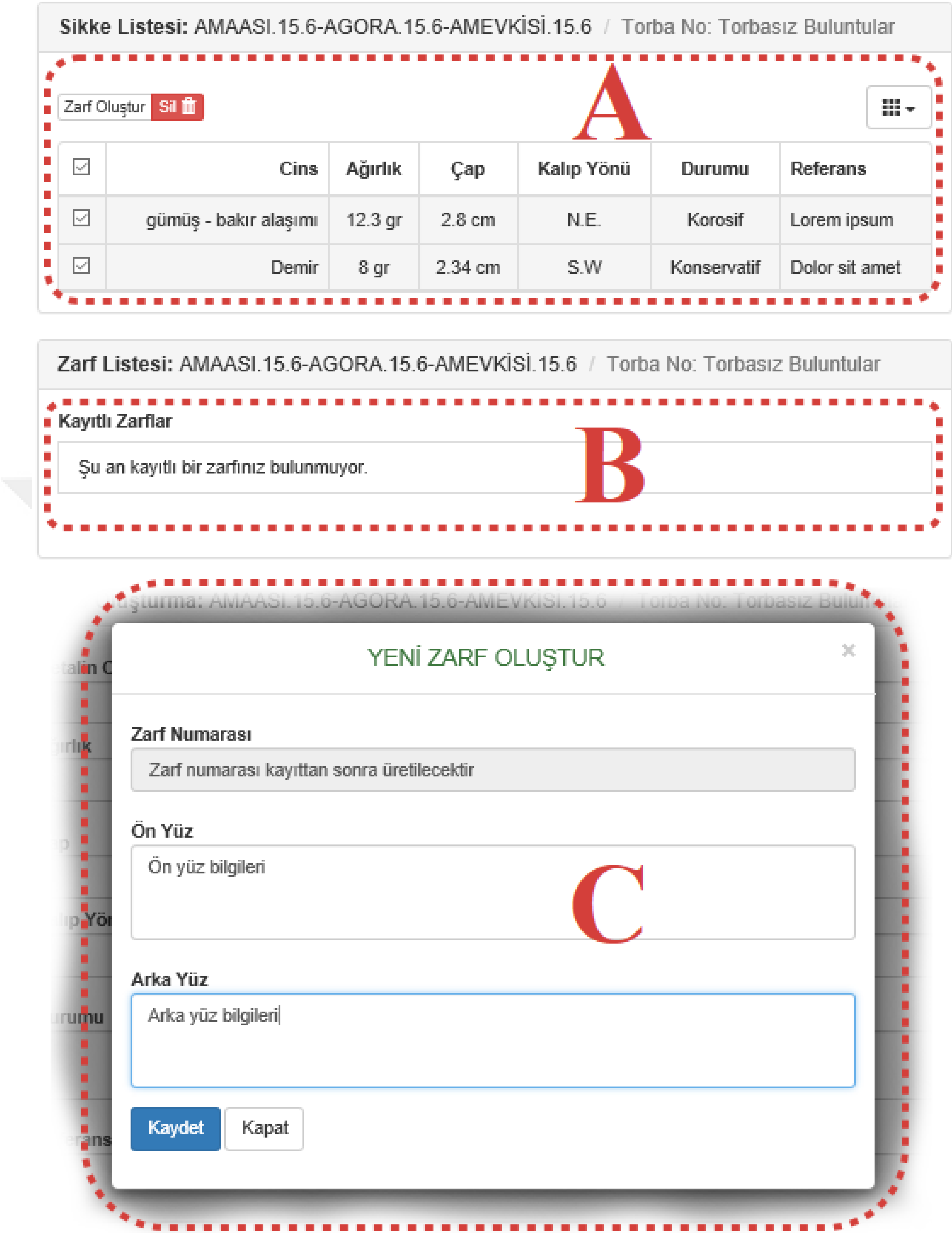


Figure 5.19 Coin station part II.

Restoration station’s user interface is shown in Figure 5.20. In this station, experts can perform several restoration methods on a particular object and document and record each of these restoration steps.

The active (“currently processing”) case and its child bags are shown in Figure 5.20 (A). The section, where experts record the restoration actions performed on given Finds, is shown in Figure 5.20 (B). In Figure 5.20 (C), recorded restoration steps, which are displayed as a list, can be seen.

Figure 5.20 Restoration station.

User interface of warehouse station is shown in Figure 5.21. The section of warehouse station page, which allows switching between “currently processing”, “incoming” and “past processed” cases, is shown in Figure 5.21 (A). Active (“currently processing”) case and its child bags can be seen in Figure 5.21 (B). Finally, warehouse information input fields, which enable recording the location information of the processed item, can be seen in Figure 5.21 (C).

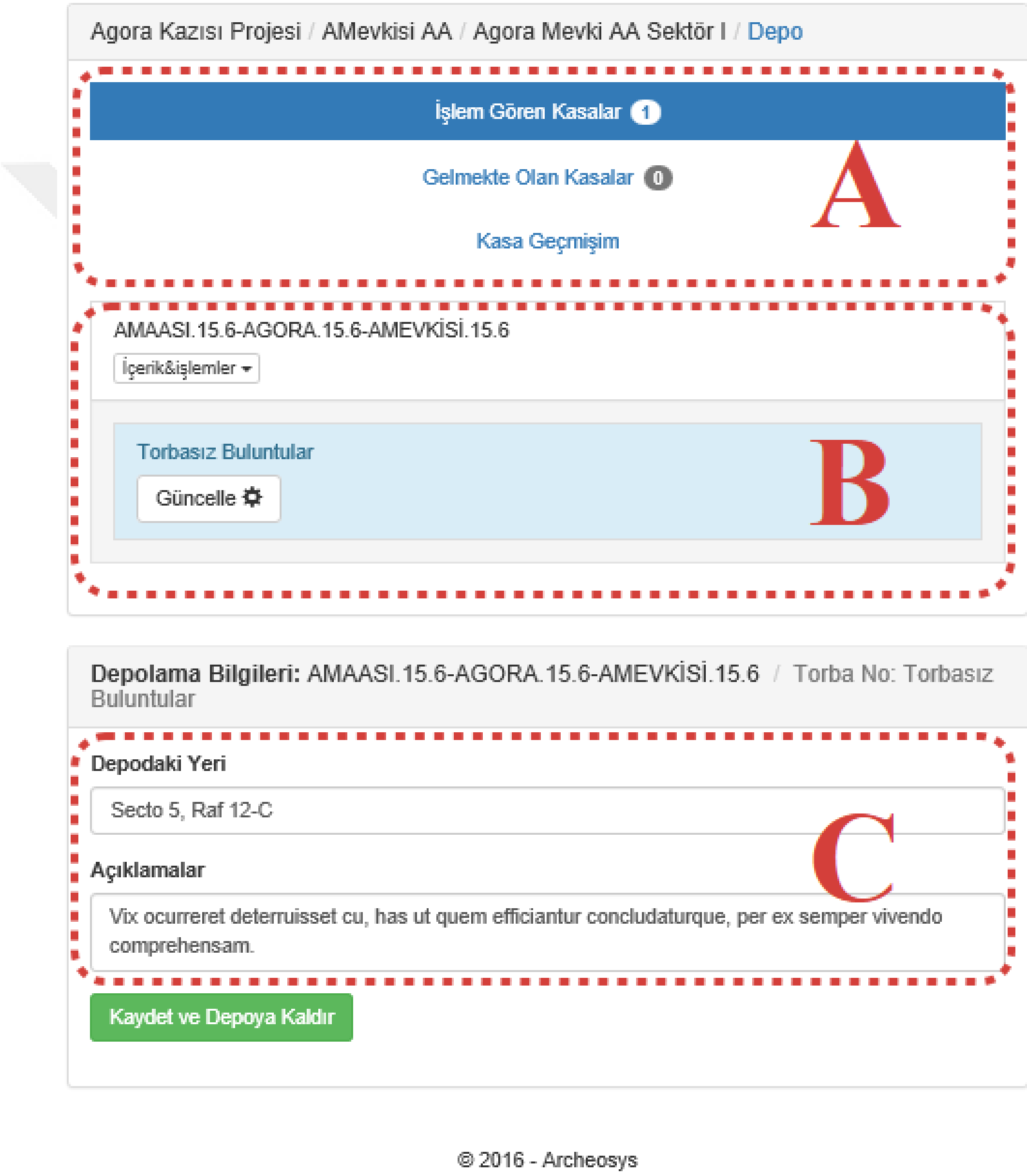


Figure 5.21 Warehouse station, mobile view.

5.4 Academic Pages

Academicians can access searching and chart generating services. Please note that, currently (January 5th 2016) these services are not fully functioning. Since Smyrna Ancient City Excavation is a long-living project, academic functionalities of Archaeosys will be fully implemented in the course time. Nevertheless, Figure 5.22, Figure 5.23 and Figure 5.24 are given for developing some intuition of what these services' user interface will look like.

Searching service is shown in Figure 5.22. Searching service must provide a detailed searching mechanism amongst the Archaeosys database. So, combining free text queries with controlled form inputs might be a good choice for getting the desired output from the searching service.

A sample output of a query is shown in Figure 5.23 as a table. Academicians should be able to filter out unwanted rows off the result set. Also they should be able to select a subset of the result set and perform analysis tools on them.

Charts are great sources to extract meaning from numeric-versus-textual data. They can help deriving knowledge from large sets of data. So, the system should also provide a flexible chart generating system. A sample of chart generating mechanism is shown in Figure 5.24 (A); and sample chart is shown in Figure 5.24 (B).

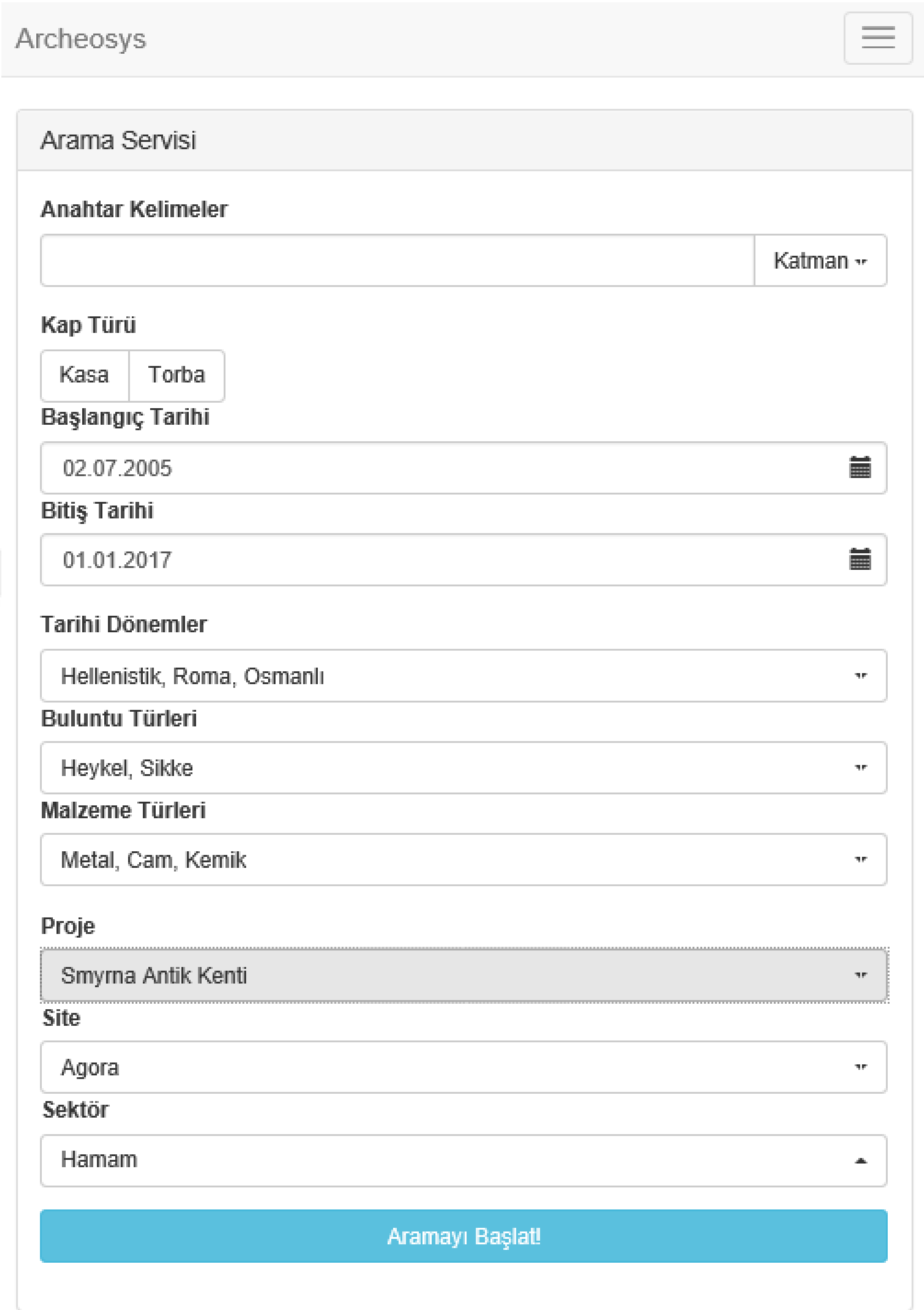
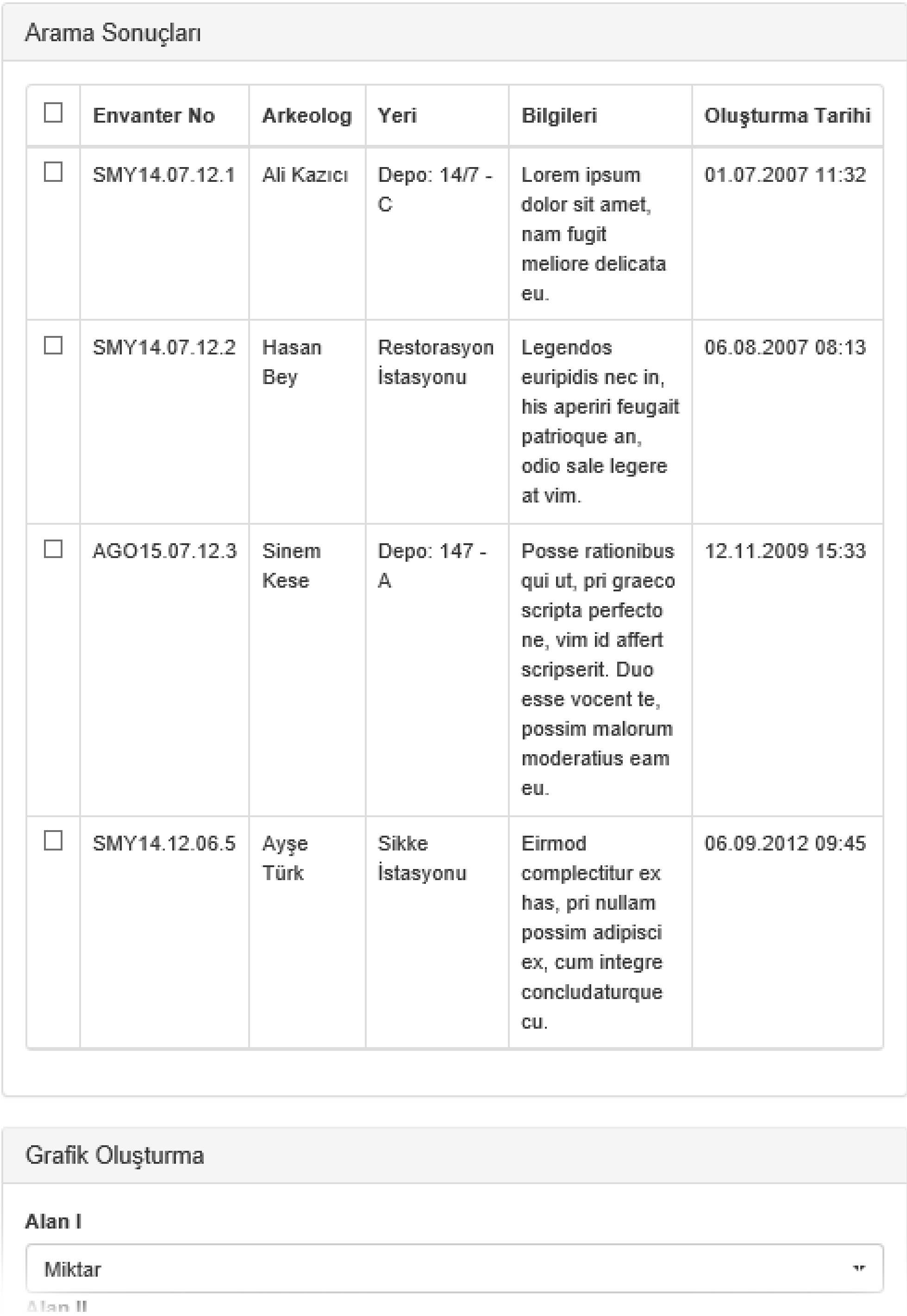


Figure 5.22 Search service page, mobile view.



☐	Envanter No	Arkeolog	Yeri	Bilgileri	Oluşturma Tarihi
☐	SMY14.07.12.1	Ali Kazıcı	Depo: 14/7 - C	Lorem ipsum dolor sit amet, nam fugit meliore delicata eu.	01.07.2007 11:32
☐	SMY14.07.12.2	Hasan Bey	Restorasyon İstasyonu	Legendos euripidis nec in, his aperiri feugait patrioque an, odio sale legere at vim.	06.08.2007 08:13
☐	AGO15.07.12.3	Sinem Kese	Depo: 147 - A	Posse rationibus qui ut, pri graeco scripta perfecto ne, vim id affert scripserit. Duo esse vocent te, possim malorum moderatius eam eu.	12.11.2009 15:33
☐	SMY14.12.06.5	Ayşe Türk	Sikke İstasyonu	Eirmod complectitur ex has, pri nullam possim adipisci ex, cum integre concludaturque cu.	06.09.2012 09:45

Figure 5.23 Search results displayed as a table, mobile view.

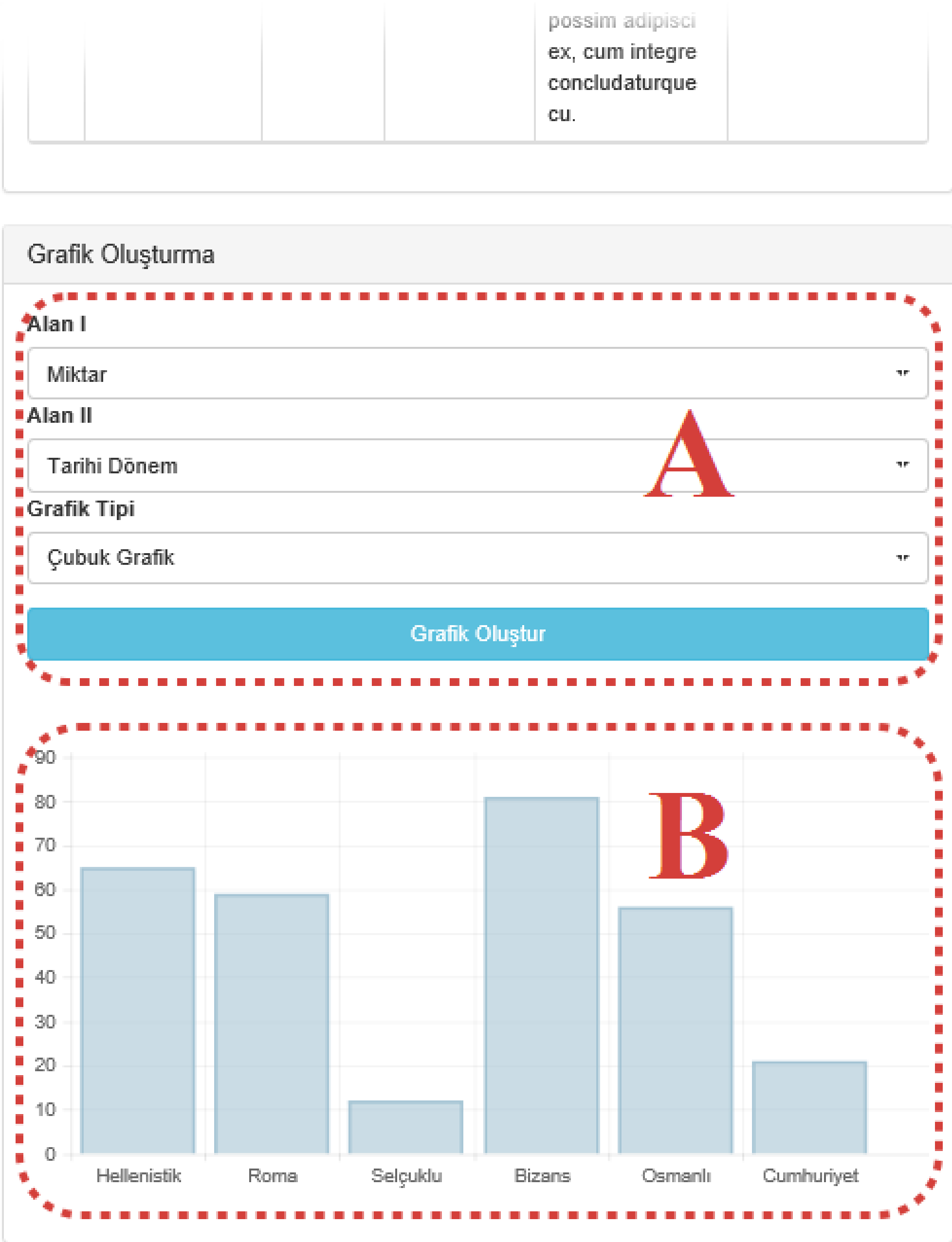


Figure 5.24 A chart generated on a searching operation.

CHAPTER SIX
CONCLUSION AND FUTURE WORK

6.1 Conclusion

Archaeosys application, which is the subject of this thesis, is found successful and utilizable by the Agora Excavation team. It is concluded that Archaeosys can provide a centralized, traceable, synchronous, robust, secure and modern data management environment for large scale archaeological excavation projects. Focusing on the field of archaeology rather than being a generic data management tool, it implements a favorable mechanism which is free from unnecessary and complicated features.

For computerized archaeological data management, MS Excel, FileMaker Pro and IADB can be considered as alternatives to Archaeosys. A comparison of these software is displayed in Table 6.1. According to the results given in Table 6.1, Archaeosys is found to be the best candidate for large scale archaeological excavation projects.

6.2 Future Work

Archaeosys application can be improved by implementing data mining and natural language processing components for its academic services. With this functionality, more comprehensive results can be derived from system's recorded data.

The second improvement suggestion is to implement an image processing component for recognizing patterns seen on Finds. By this functionality, application can automatically detect Finds' historical origins and make recommendations to station personnel.

The third enhancement suggestion is implementing an image processing component for restoration station which can detect broken pieces of an item and virtually reconstructs it like a puzzle.

And finally, a 3D scanning system combined with virtual reality technology can be used for creating a virtual touring environment for archaeological site.

Table 6.1 Comparison of Archaeosys, MS Excel, FileMaker Pro 14 and IADB.

	Archaeosys	**MS Excel**	**FileMaker Pro 14**	**IADB**
Supports relational data	✓	✗	✓	✓
Platform	Web browsers	Windows	Windows Web browsers OS X	Web browsers
Ease of use	Easy	Easy	Needs training	Needs training
Scalability	Multiple concurrent users	1 concurrent user	Multiple concurrent users	1 concurrent user
Security	Password protection	Password protection	Password protection	Password protection
Cost	N/A	$7-$10/Month	$549	Free
Focused on archaeology	✓	✗	✗	✓
Role based authorization	✓	✗	✓	✓
Mobile support	All devices having web browsers	Windows Android	iPad iPhone	iPad iPad Mini
Requires installation on client machine	✗	✓	For mobile devices, yes	For mobile devices, yes
Work offline	✗	✓	✓	For mobile devices, yes
Storable data types	Any type	Alphanumeric Image	Any type	Any type
Scheduled backup	✓	✗	✗	✓
Centralized	✓	✗	✓	✓
Supports inter-station flowage	✓	✗	✗	✗

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