Management & Functional Use of Mineral Resources in Ancient Sri Lanka: Stone as a Building Material in Ancient Anuradhapura

Dissertation

by

Thusitha Wagalawatta

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First Supervisor
Prof. Dr. Brigitta Schütt
Freie Universität Berlin
Department of Earth Sciences
Physical Geography
Malteserstraße 74-100
12249 Berlin
Germany

Second Supervisor
Prof. Dr. Kay Kohlmeyer
University of Applied Sciences (HTW)
Department 5 – Gestaltung und Kultur
Wilhelminenhofstraße 75A
Berlin
Germany

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"Buddhist influence, the efficient cause of all the constructive energy which the Singhalese displayed in the erection of their vast cities and monuments"

Henry Cave
British writer who visits Sri Lanka in 1896

Dedicated to my loving family

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Abstract

The ancient city of Anuradhapura, located in north-central Sri Lanka was capital of the Singhalese kingdom between the 4^{th} century BCE and the 11^{th} century CE. The slightly rolling landscape in the surrounding of the ancient city is structured by a linear rock outcrop line, which is located west of the city and the course of the River Malwathu Oya, flowing in northern direction and passing the city to the east.

The architecture of Anuradhapura is characterized by a mixed material tradition utilizing parallel burnt bricks, timber and stone blocks as construction materials. Remains of numerous ancient buildings and monuments occur throughout the entire settlement. The majority of foundations, floor areas, pillars and entrance units of the buildings consist of stone blocks and provide evidence that rocks were the primary building material used for the constructions of buildings. In general the availability of natural resources plays a pivotal role by sustaining the foundation and successive development of the (ancient) settlements. This doctoral thesis is focusing on the availability and exploitation of bedrock as natural resource for construction material. The methodological approach applied encompasses a) a systematic survey of outcropping bedrocks in the surrounding of the ancient city of Anuradhapura in order to identify ancient quarries, b) a survey of remains of ancient building in the center of the ancient city to analyses the constructional contexts of different rock types, c) sampling of bedrock and building rocks to analyses whose petrographic, geochemical and mineralogical character and d) ethno-archaeological investigations to gain a better understanding of ancient stone quarrying techniques.

Altogether 65 ancient quarry sites were identified in the settlement area and are classified into six categories. Most of the quarries are located along the rock outcrop line. All quarry locations were identified based on quarry marks, which appear as chiseled quarry holes on parent and quarried rocks. Separating stone blocks from rock exposures is done by drilling a line of holes with a chisel in the rock, putting wedges in the holes and then applying pressure

on the line of holes with a hammer. This is the most the most prominent quarrying technique utilized in the surrounding of Anuradhapura. After the exploitation of stone blocks, numerous ancient quarry areas were integrated into the built environment as basins for water storage, rock shelters as living space or as leveled platforms on top of large boulders, which served as foundation to erect sacred buildings. A comparison of petrographic, mineralogical and chemical characteristics of analyzed bedrock samples show, that ancient architects preferred the usage bedrock from local sources as a construction material for ordinary purposes. Marble was exclusively used for ornamentation in highly sacred Buddhist constructions during the later periods of Anuradhapura (after 6th century CE). As marble does not occur in the study area, all marble rocks in Anuradhapura, represents imports. It is concluded, that its utilization coincides with the development of the capital as a place of centralized political and religious power. In contrast, the availability of gneissic bedrock, naturally accessible in outcrops, was an important factor which supported the development of Anuradhapura as capital of the first kingdom in Sri Lanka.

Zusammenfassung

Die Stadt Anuradhapura befindet sich im zentralen Norden Sri Lankas und war vom 4. Jh. v. Chr. bis zum 11. Jh. n. Chr. die Hauptstadt des singhalesischen Königreichs. Die leicht hügelige Landschaft wird durch eine markante Störungslinie, mit oberirdisch anstehenden Gneisen, westlich der Stadt dominiert. Östlich der Stadt verläuft der nach Norden entwässernde Fluss Malwathu Oya. Die Architektur von Anuradhapura ist von der Verwendung verschiedener Materialien wie gebrannter Ziegel, Holz und Steinblöcke geprägt. Reste zahlreicher antiker Gebäude und Denkmäler sind über die gesamte Siedlungsfläche verteilt. Die Mehrheit der Fundamente, Böden, Säulen und Eingangsbereiche der Gebäude bestehen aus Steinblöcken. Dies zeigt, dass bearbeitete Steine der wichtgiste primäre Baustoff für die Konstruktionen von Gebäuden waren und verdeutlicht die Wichtigkeit der Verfügbarkeit natürlicher Ressourcen für die Gründung und sukzessive Entwicklung der (ehemaligen) Siedlung.

Diese Dissertation konzentriert sich auf die Verfügbarkeit und die Erschließung von anstehendem Gestein für die Nutzung als natürlicher Baustoff. Der angewandte methodische Ansatz umfasst eine systematische Kartierung von Gesteinsaufschlüssen in der Umgebung Anuradhapuras, um die Lage antiker Steinbrüche zu bestimmen. Des Weiteren zeigt eine systematische Übersicht der baulichen Überreste alter Gebäude im Zentrum der alten Stadt, in welchem Kontext die verschiedenen Gesteinsarten verwendet wurden. Diese Übersicht wird ergänzt durch petrographische, geochemische und mineralogische Analysen von Proben des Ausgangs- sowie Baugesteins. Komplementär dazu wird eine ethno-archäologische Untersuchung durchgeführt, die zu einem besseren Verständnis der antiken Steinbruchtechniken beiträgt.

Insgesamt wurden 65 Steinbrüche im Siedlungsgebiet identifiziert und in sechs Kategorien eingeteilt. Die meisten der Steinbrüche sind entlang der Störungszone, wo das Gestein oberirdisch ansteht, gelegen. Alle Steinbrüche wurden anhand von Bearbeitungsspuren bestimmt, die als gemeißelte Löcher im Ausgangsgestein und den bearbeiteten Blöcken in Erscheinung treten. Die in der Umgebung von Anuradhapura am weitesten verbreitete Methode des Abtrennens

von Blöcken vom Ausgangsgestein basiert auf dem Anlegen dieser Bohrlöcher. Diese wurden als Linie mit einem Meißel in den Fels getrieben, anschließend wurde mit einem Hammer Druck aufgebaut und der Block entlang der Linie gelöst. Nach der Gewinnung der Steinblöcke wurden zahlreiche der ehemaligen Steinbrüche baulich in die Umgebung integriert. Die Nachnutzungsarten umfassen Becken zur Wasserspeicherung, überhängende Felsdächer als Wohnraum oder eingeebnete, höher gelegene Plattformen als Untergrund für Sakralbauten.

Ein Vergleich der petrographischen, mineralogischen und chemischen Eigenschaften der Gesteinsproben zeigen, dass die antiken Architekten die Nutzung des Ausgangsgesteins aus lokalen Quellen als Baustoff für profane und gewöhnliche Gebäude bevorzugten. Marmor wurde ausschließlich für Verzierungen in buddhistischen Bauten mit Repräsentationsfunktion in den späteren Perioden von Anuradhapura (nach dem 6th jahrhundert CE) verwendet. Da Marmor nicht im Untersuchungsgebiet vorkommt ist es ein Indiz für Importe. Dabei ist festzustellen, dass die Verwendung dieses Rohstoffes mit der Entwicklung der Hauptstadt zu einem Zentrum der politischen und religiösen Macht verbunden ist. Die Verfügbarkeit von Gneisen aus natürlichen Aufschlüssen kann als ein weiterer entscheidender Faktor für die Entwicklung von Anuradhapura als Hauptstadt des ersten Reiches in Sri Lanka gesehen werden.

සාරාංශය

ශ්‍රී ලංකාවේ උතුරු මැද පළාතේ පිහිටා ඇති අනුරාධපුර නගරය ක්‍රිස්තු පූර්ව 4 වැනි සියවසේ සිට 11 වැනි සියවස අතර කාලය තළ පැවැතුනු ශ්‍රී ලාංකික රාජ්‍යයේ අගනුවර විය. මදක් තැනිතලා භූමියක පිහිටා ඇති නගරය එහි බටහිර පෙදෙසේ පිහිටා ඇති රේඛීය ගල් කුළකින් ද එහි නැගෙනහිර පෙදසින් ගලා බසින මල්වතු ඔය නිම්නයෙන් ද වට වී ඇත.

අනුරාධපුර නගරයේ පැරණි ගොඩනැගිලි සහ අනෙකුත් වාස්තු නිර්මාණයන් ගඩොල්, දැව සහ පාෂාණ පුවරු භාවිතයෙන් නිර්මාණය කර ඇත. එම නිර්මාණයන්ගේ අවශේෂයන් පැරණි නගරය පුරාවටම විසිරි පවතිනු දැක ගත හැකි ය. ශේෂ වී ඇති විශාල ප්‍රමාණයක් වූ ගොඩනැගිලි පාදම්, ස්ථම්භයන්, සහ දොරටු අංග නිර්මාණ දෙස බලීමේ දී පාෂාණ වර්ග ඓතිහාසික ඉදිකිරීම්වල ප්‍රධාන අමුද්‍රව්‍ය බව තහවුරු වේ. සාමාන්‍ය වශයෙන් ගත්කල ඓතිහාසික යුගයන්හිදී ජනාවාස බිහිවීම සහ ඒවායේ වර්ධනය සඳහා ස්වභාවික සම්පත්වල පිහිටීම වැදගත් ලෙස බලපා ඇත. මෙම ආචාර්ය උපාධි නිබන්ධනයේ අරමුණ වන්නේ ස්වභාවික සම්පතක් ලෙස මාතෘ පාෂාණයන්ගේ පිහිටීම සහ ඒවා පරිහරණයට ගත් ආකාරය ඓතිහාසික අනුරාධපුර නගරය ආශ්‍රය කොටගෙන විමර්ශනය කිරීමයි.

මෙම අධ්‍යනය සඳහා ක්‍රම වේදයන් කිහිපයක් අනුගමනය කරන ලදී. ඒවා පිළිවෙළින් මෙසේ දැක්විය හැකිය. a) ඓතිහාසික යුගයන්හිදී ගොඩනැගිලිද්‍රව්‍ය සපයාගත් පැරණි ගල් කොරි හඳුනා ගැනීම උදෙසා සිදුකරන ලද ප්‍රාදේශීය පාෂාණ උද්ගත පිළිබඳ සමීක්ෂණය. b) ඓතිහාසික ගොඩනැගිලි නිර්මාණය කිරීමට භාවිතා කර ඇති විවිධ වර්ගයේ පාෂාණ හඳුනා ගැනීමට සහ එම නිර්මිතයන් විශ්ලේෂණය කිරීම උදෙසා කරන ලද ක්ෂේත්‍ර අධ්‍යයනය. c) පාෂාණ අමුද්‍රව්‍යයන්ගේ භූවිද්‍යාත්මක සහ රසායනික තත්ත්වයන් හඳුනාගැනීම සඳහා සිදුකරන ලද පැරණි ගොඩනැගිලි සහ මාතෘ පාෂාණ නියැදි එකතුව සහ d) ඓතිහාසික යුගයේ පාෂාණ නෙලාගැනීමට අනුගමනය කරන ලද විධික්‍රමයන් හඳුගැනීම සඳහා කරන ලද මානව පුරාවිද්‍යා අධ්‍යයනය.

මෙම අධ්‍යයන තුළින් ප්‍රදේශයේ ඓතිහාසික යුගයේ භාවිත කර ඇති ගල් කොරි ස්ථානයන් 65 ක් හඳුනාගත් අතර ඒවා ප්‍රභේද 6 ක් යටතේ වර්ග කරන ලදි. බොහෝමයක් වූ මෙම පැරණි ගල් කොරි පැරණි නගරය අතුරින් දිවෙන රේඛීය ගල්කුළු (දීර්ඝ පාෂාණය) මත පිහිටා ඇත. මෙම සියලූම පැරණි ගල් කොරි, හඳුනා ගන්නා ලද්දේ මාතෘපාෂාණ මත තවදුරටත් දැකිය හැකි ඓතිහාසික යුගයේදී පාෂාණ නෙලා ගැනීම සඳහා සකසන ලද සිදුරු සාධක අනුව ය. මාතෘ පාෂාණයන්ගෙන් පුවරු වෙන්කර ගැනීම සඳහා ඓතිහාසික යුගයේ දි භාවිත කරන ලද ප්‍රධානතම විධික්‍රමය වන්නේ ගල් කටු භාවිතයෙන් පාෂාණ පෘෂ්ඨය මත සිදුරු පේලියක් විද, ඒවා තුළට ගල් කුඤ්ඤ ඇතුලුකොට මිටියක් මගින් ඒවා සීරුවෙන් සිදුරු තුළ සිරකිරීමෙන් ලැබෙන තෙරපුම ප්‍රයෝජනයට ගැනීමෙනි. ප්‍රමාණවත් ලෙසින් පාෂාණ කොටස් නෙලාගැනීමෙන් අනතුරුව බොහෝ පැරණි කොරි අවකාශයන් විශේෂයෙන්ම ජලය එකතු කිරිම සඳහා පොකුණු ලෙස ද ගල් ගුහාවන්ගේ වාසස්ථාන අවකාශයන් පුල් කිරිම සඳහා සහ උස් පාෂාණ උද්ගතයන්ගේ ඉහළ තලයන් පූජනීය ගොඩනැගිලි ඉදිකිරිම සඳහා පාදම් සථාන ලෙසින් ද භාවිත කර ඇත.

නිර්මිත පරිසරයේ ගොඩනැගිලි අංග තුළින් ලබාගත් නියැදීන්ගේ ඛණිජ විද්‍යාත්මක සහ රසායන විද්‍යාත්මක ගුණාංග මාතෘ පාෂාණවලින් වෙන් කරගන්නා ලද නියැදියන්ගේ ගුණාංගවලට සමාන වීම තුළින් පෙනීගිය කරුණ වන්නේ පැරණි ගෘහ නිර්මාණ ශිල්පීන් තම මූලික ඉදිකිරීම් සඳහා අවට ප්‍රදේශයේ සම්පත් මූලයන්ගෙන් අමුද්‍රව්‍ය සපයාගෙන ඇති බවයි. ගොඩනැගිලි අලංකරණ සහ පූජනීය ගොඩනැගිලි නිර්මාණය කිරීම සඳහා පසුකාලීන අවධීන්හිදී ගරුඬපාෂාණ ද භාවිතා කොට ඇත (ක්‍රිස්තු වර්ෂ 6 වැනි සියවසෙන් පසු කාලයේදි). ගරුඬපාෂාණ උද්ගතයන් පැරණි නගරය ආශ්‍රයේ පිහිටා නොමැති බව තහවුරු වූ කරුණක් බැවින් ඒවා සියල්ල ආනයනය කරන ලද ඒවා බව තහවුරු වේ. එබැවින් කරුණු සමුච්චය කර කිව හැක්කේ අනුරාධපුර නගරය දේශපාලනික සහ ආගමික කේන්ද්‍ර ප්‍රදේශයක් ලෙස විකාශනය වීමත් ගරුඬපාෂාණ ආනයනික අමුද්‍රව්‍යක් ලෙස නිර්මිත පරිසරයට ආගමනය වීමත් එකිනෙකට සමපාත වන බවය. ඊට ප්‍රතිවිරුද්ධ ආකාරයටල ප්‍රදේශයේ සුලබව පවතින සහ සවිශක්තියෙන් යුතු ග්නයිසික පාෂාණ අනුරාධපුර ජනාවාසය මූලික වශයෙන් ස්ථානගත වීමටත් අගනගරයක් ලෙසට ස්ථිරසාරව දියුණුවට පත් වීමටත් බලපා ඇති බව පෙනි යයි.

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CHAPTER 1

Introduction

The ancient city of Anuradhapura existed as the capital of the Sri Lankan kingdom in north-central Sri Lanka from the 4th century BCE to the 11th century CE. The comprehensive architectural remains of Anuradhapura make it one of the most important archaeological sites in the cultural landscape of Sri Lanka. Even today, the ruins of sacred and residential constructions are evidence of the outstanding architectural and artistic culture that existed during the Anuradhapura period (Bandaranayake, 1974, 7).

The ancient architecture of Anuradhapura is characterized by a mixed material tradition that used parallel burnt bricks, timber and stones (Bandaranayake, 1974, 375). However, the majority of foundations, floor areas, pillars, and entrance units of the buildings consist of stone blocks and provide evidence that rocks were the primary building material used for the construction of monumental buildings or elements during the Anuradhapura period. Gneissic rocks were the preferred building material in the ancient built environment of Anuradhapura.

Topographically the area around Anuradhapura is a gently rolling plain. East of the city, the River Malwathu Oya flows in a northerly direction. Bedrock is dominated by metamorphic rocks (Kröner et al., 2013; Cooray, 1995, 4). Superficial rock exposures are rare in the area due to a thick saprolite cover (Ball and Herbert, 1992). The few rock exposures in the area occur west of the city along a linear outcrop, which runs from south to north. The majority of ancient architectural features, the Citadel as the fortified center of the ancient city and many of the monasteries, were situated between the Malwathu Oya River and the rock outcrop line.

The research aims to investigate ancient rock quarries and quarrying techniques, landscape dynamics related to resource exploitations and the origin of stones utilized as building materials in the ancient city of Anuradhapura. To achieve these aims the ancient built and natural environment of the ancient city was investigated with three different objectives. For each of the objectives a publication has been prepared:

- The localization and classification of quarry sites as the source areas of building material for historical constructions and associated landscape evolution were investigated in the hinterland of Anuradhapura in Wagalawatta et al. (2015): ‘Ancient Rock Quarries in Anuradhapura, Sri Lanka’ (own contribution 65%). In this study, sixty-five ancient quarry sites were recorded and classified into six types. Their spatial distribution was analyzed, and the re-occupation of the former quarries was assessed to derive information about landscape evolution related to the quarrying activities. Moreover, different kinds of quarrying strategies were identified, which were applied in accodance with the morphology of the outcrop.

- ‘An ethnoarchaeological study of stone quarrying techniques at historic Anuradhapura’: Wagalawatta et al. (in press), (own contribution 90%). The investigated quarry locations were identified based on chiseled quarry hole evidence on the parent rocks. Consequently, it is assumed that this method was a prominent rock quarrying technique among the ancient stoneworkers. This ethnoarchaeological investigation was conducted to gain knowledge about what kinds of tools were used and how the quarry fractures were generated. As a result, it was possible to show that ancient stone cutters used iron chisels to bore the holes, that wedges were used for the splitting process and that stone cutters purposely chiseled oval-shaped holes in order to create a consistently straight splitting fracture line.

- The assessment of ‘the significance of stone resources in the cultural landscape of ancient Anuradhapura’ was undertaken by Wagalawatta et al., (submitted; own contribution 65%). The investigation illustrates that ancient people took advantage of the morphological situation of outcropping rocks in the settlement as landscape features favoring the establishment of a permanent settlement on the banks of River Malwathu Oya while extracting building materials for constructional purposes. Moreover, the scarcity of outcropping bedrock in the area and the physical properties of granitic materials, such as their structures and hardness, were used facilitated by ancient constructers. However, consumption of the limited amount of marble materials demonstrates that there a predisposition to use exotic materials on particular constructions for ornamenation and decoration, subsequent to the initial development of the settlement.

The results of these publications are briefly synthesized in Chapter 8. The building and source rock samples which from the basis of this investigation are compiled in a catalogue (Appendix 2) to illustrate information about the origin and resource mobility of the ancient city of Anuradhapura. The catalogue will be published in 2017.

CHAPTER 2

State of the Art

2.1. Settlement history of Anuradhapura

The oldest settlement evidence of Anuradhapura goes back to the Early Iron Age and dates to 900-600 BCE based on radiocarbon analysis (Deraniyagala, 2004b, 709). This evidence includes, for instance, black and red ware pottery and iron objects. Additionally, there is evidence of the occurrence of domesticated cattle and on rice cultivation (Deraniyagala, 2004b, 155; Coningham, 1999, 129) (Appendix 1). By 800 BCE, the spatial extent of the Early Iron Age settlement exceeded 10 hectares, while c. 200 years later, between 700 and 600 BCE, the settlement area reached about 50 hectares (Deraniyagala, 2004b, 709; Coningham, 1999, 127).

The period recognized as the Basal Early History of Anuradhapura (600-500 BCE) (Appendix 1) corresponds to the time when the traditional history of Anuradhapura begins. Potsherd fragments with Brahmi inscriptions excavated in the Citadel of Anuradhapura bear witness to the introduction of writing, and have been dated to 500 – 600 BCE by thermoluminescence dating (Deraniyagala, 2004b, 741). The Brahmi characters are almost identical to the Asokan script in India (Paranavithana, 1970, xxi; Deraniyagala, 2004b, 739; Coningham et al., 1996, 83).

As Mahawamsa states (the Mahavamsa is the great chronicle that includes information about socio-economic, political, and religious aspects of Sri Lankan history), an Indian prince called Vijaya migrated from India with his cortege and landed on the north-west coast of Sri Lanka in the 5th century BCE. Thereupon, Prince Vijaya became the king of Sri Lanka (reign 543-505 BCE), founding his settlement in the center of the island (Mahavamsa, 1912, 56). His minister Anuradha founded a settlement on the banks of the River Malwathu Oya which later become the capital, for which reason the settlement was initially named Anuradhagama, (Anuradha +

gama = Village of Anuradha).

The urbanization of the later Anuradhapura begins during the Lower Early Historical Period (500- 250 BCE) (Deraniyagala, 2004b, 712), (Appendix 1), coinciding with the arrival of Buddhism (c. 300 BCE) (Mahavamsa, 1912, 91; Cave, 1907, 34; Bandaranayake, 1974, 11). According to the Mahavamsa description, King Pandukabaya (reign 437-367 BCE), developed the rural Anuradhagama settlement as a capital and re-named it Anuradhapura (Anuradha + pura = city of Anuradha) (Mahavamsa, 1912, 73). Moreover, he established separate residential sectors according to social cast and also set up a security force to protect the city from enemies. In addition, he initiated the construction of multiple sanctum for the ascetics (Mahavamsa, 1912, 75).

From the beginning of the Mid Early Historical Period (250 BCE-100 CE) (Appendix 1) the city of Anuradhapura extended its sovereignty over the entire hinterland (De Silva, 2000; Mendis and Weerasekara, 2013). Ongoing, the city of Anuradhapura rapidly developed as a royal and Buddhist city with various residential and religious sectors (Citadel, major and minor monasteries), including some small reservoirs and the agricultural hinterlands (Seneviratne, 1987; Seneviratne, 1994, 24; Cave, 1907, 35).

In the Upper Early Historical Epoch (100-300 CE) large-scale settlements grew with a water supply based on major reservoirs that were parallel to the demographic expansion constructed in the hinterlands of Anuradhapura (Seneviratne, 1984). The materials excavated in the Anuradhapura Citadel, such as ceramics industry imported from areas from Northern India to the Mediterranean region (Deraniyagala, 2004b, 718; Coningham, 1999, 126; Coningham, 2006, 5), also illustrate the supra-regional importance of the city, especially during Middle History (300-1250 CE) (Appendix 1).

The city of Anuradhapura served as the capital under the reign of 124 kings over approximately 1300 years. It collapsed in 1017 CE during the era of King Mahinda V (reign. 981 - 1017 CE) (Paranavithana, 1933, 4). Thereafter the Singhalese kingdom was unstable until King Vijayabahu I (1055 AD) came into power and elected Polonnaruwa as the new capital of his kingdom (Chulawamsa, 1953, LVIII).

2.2. Ancient architecture of Anuradhapura

Preserved living floors in the archaeological records from the excavation of the Citadel in Anuradhapura give evidence that wattle and daub constructions were the preferred materials of the earliest architectural constructions in Anuradhapura, dated to the Early Iron Age (Coningham, 1999, 129; Coningham, 2006, 5) (Appendix 1) (Figure 2.1a). Coningham (1999, 128) assumes that these early buildings were probably roofed with grass or palm leaves. Simultaneously, ancient written sources provide evidence about wattle and daub architecture mentioning the 'kalaprasada' (black house) which was the place of residence of the Buddhist monk Mahinda (307 BCE) (Mahavamsa, 1912, 112) (Figure 2.1a).

After the arrival of Buddhism in Sri Lanka in the 3rd century BCE natural rock shelters were frequently utilized as living compartments by Buddhist monks. It is stated in the Mahavamsa that King Dewanampiyathissa (reign 307-267 BCE) converted natural rock shelters into living compartments and donated them to the Buddhist monks (Mahavamsa, 1912, 112). A prominent architectural feature of these converted rock shelters are drip ledges, curved embossed sections above the roof portals that prevent rainwater dripping into the cave chamber (Bandaranayake, 1974, 46; Coningham, 1995, 229) (Figure 2.1c).

From the Lower Early Historical Period burned bricks were the prevailing construction material in Anuradhapura (500-250 BCE) (Deraniyagala, 2004b, 712; Deraniyagala, 1972, 58). The description of Mahawamsa also confirms the usage of burned bricks for the major constructions in the contemporary period regarding the construction of the Ruwanveli stupa (Mahavamsa, 1912, xxix). As the archaeological evidences reveal (Coningham, 1999, 126-129; Coningham, 2006, 5; Deraniyagala, 2004b, 719), and written chronicles describe (especially the Mahavamsa), the utilization of stone blocks as construction materials was not common before the Mid Early Historical Period (250 BCE-100 CE).

In the ancient monasteries of Anuradhapura most of the preserved constructions are the remains of solid masonry buildings and they were most likely constructed after the 5th century CE (Bandaranayake, 1974, 7) (Figure 2.1d). The majority of the monastic buildings were constructed using various types of raw materials such as bricks, rocks and timber simultaneously (Figure 2.1d). The lost upper structures of the monuments, notably the roofs and the upper walls, were created using perishable materials such as timber (Bandaranayake, 1974, 15). However, the majority of the foundations, floor areas, pillars, and entrance units of the ancient buildings as well as the non-building architecture of the built environment such as ramparts, bridges and irrigation architecture consist of stone material. They provide evidence that stones were the prominent building material used for construction during the Anuradhapura period (Figure 2.1d) (Appendix 2).

Some of the architectural evidence unearthed from the excavations of the Citadel proves that ancient people re-used the building materials, especially stone slabs (Kohlmeyer, 2010). Moreover, many historic constructions in the monasteries also provide some evidence of the subsequent re-usage of building materials for other purposes (Figure 2.2). In consequence, although it is possible to assign the construction of some major monasteries and tanks to the reign of certain kings, the identification of specific building phases and a precise dating of the preserved ruins are difficult.

Figure 2.1.: Landmarks of the architectural history of Sri Lanka. (a) Constructing a wattle and daub house, following the primitive methods (Kebithigollewa Buddhist temple in 2010) (b) Prepared natural rock shelter. The drip ledge can be seen over the roof portal (Vessagiriya monastery 2014). (c) Conventional monastic architecture: constructed using stone and brick materials (Abayagiriya monastery 2014) (Photographs taken by Wagalawatta.)

Figure 2.2.: Evidence about re-used building materials; (a) The red arrowhead points to a foundation slab in the Vijayabahu palace (10^{th} century CE) (Citadel). It is a fragment of a former door or window frame. (b) Fragment of a 'slab of inscription' used as a paving stone (Asokaramaya monastery) and (c) a former 'pillar Inscription' used as a foundation slab (temple of the tooth relic in the Citadel) (Photographs taken by Wagalawatta.)

2.3. Structure of the ancient city

The ancient city of Anuradhapura is structured by different functional units (Seneviratne, 1994, 82; De Silva, 2000), including the Citadel, major and minor monastic complexes and reservoirs. The central part of the ancient city is represented by the area of the Citadel, which functioned as the inner royal settlement, surrounded by a rampart and a moat (Seneviratne, 1994, 19). The area covered by the Citadel totaled approximately 100 hectares (Deraniyagala, 2004b, 709). Coningham (1999, 15) states that the accumulation of prestige materials unearthed during the excavations in the Citadel reflects the various overlapping chronological sequences of its history (Appendix 1).

The major monasteries (locally called mahavihara) are located immediately adjacent to the Citadel (Figure 3.1c). The internal structure of each Mahavihara consists of residential and sacred buildings such as image houses, Bodhi tree houses, meditation centers, health care centers, alms halls (Sinhala dhanasala), and water management units. The prime architectural symbol of each Mahavihara is a gigantic stupa which is generally located in the center of the monastery (Figure 3.1c and Figure 3.2). The residential buildings of the major monasteries consistently appear as clusters. Internal ramparts separate each single building or building cluster of the monastery: the entire monastery was also surrounded by a rampart.

Inside its territory, the city of Anuradhapura also consisted of numerous ancient reservoirs, locally called Wewa or Kulama. The four major tanks Perimiyankulama, Bulankulama, Basawakkulama, and Tisawewa (Figure 3.1c) are located west of the rock outcrop line (Figure 3.1c). These four tanks are connected by the Jayagaga channel and receive their water from Kalawewa (Murphey, 1957, 184). Only the Nuwarawewa is located east of the Malwathu Oya (Figure 3.1d).

A few minor monasteries, established on the rocky surfaces or artificially elevated terraces, are located along the frontier of the ancient city territory. Usually, these monasteries were surrounded by a water moat. Each of these monasteries included residential, religious and water management units. The religious and residential buildings forming the minor monasteries were less in number and size than in the case of the major monasteries. The utilization of natural rock shelters as residential compartments or religious chambers, and the positioning of sacred buildings (notably, stupas) on the elevated rock outcrops were frequent within these monasteries.

De Silva (2000) presents the structure of the ancient city of Anuradhapura with a circular structural model (Figure 2.3). He suggests that the ongoing population growth, the Buddhism and the agro-settlements of ancient Anuradhapura further expanded to occupy land at with increasing distances (De Silva, 2000).

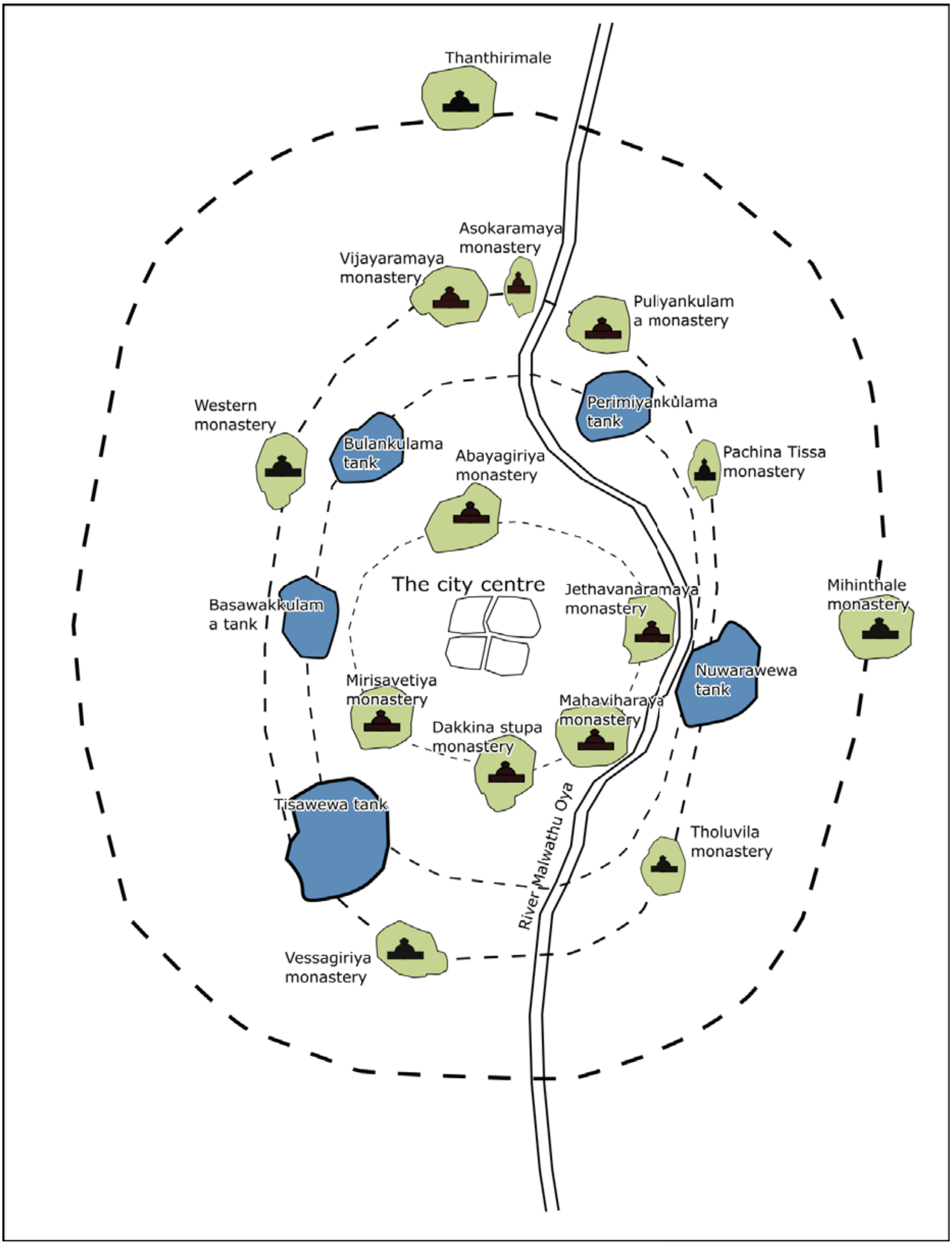

Figure 2.3.: Structure of ancient Anuradhaupura and its vicinity; (1) Citadel and the adjoining three monastery complexes representing the inner circle, (2) the circle of the ancient reservoirs, (3) minor monasteries and (4) marginal territory; modified after De Silva (2000).

CHAPTER 3

Study Area

3.1. Location and relief of Anuradhapura

Sri Lanka is an island situated in the Indian Ocean (79°82’ E, 6°10’ N), 50 km southeast of the Indian subcontinent (Figure 3.1a). The island extends 430 km from north to south and 225 km from west to east with a total area of 65,000 km2. Three major landscape units are defined by the elevation levels: the up country (Central Highland), the mid country, and the low country (Lowlands) (Goonewardene and Dent, 1993). The city of Anuradhapura is located in the northern lowlands (8°21’ N, 80°23’ E; 89 m asl) and is currently the capital of the North Central Province.

The regional land surface in the area around Anuradhapura corresponds to a gently rolling plain with some isolated hills (inselbergs), (Figure 3.1d and Figure 3.2), inclining from west to east (Department of Survey, 1988). The drainage in the region is dominated by the rivers Malwathu Oya, Kal Aru, Modatagam Aru, Kala Oya and Mi Oya, all discharging into the Indian Ocean (Coningham, 1999, 9; Figure 3.1d). The local topography in the environs of the ancient city of Anuradhapura slightly declines to the east, towards to the River Malwathu Oya. In general, the regional topography of Anuradhapura is characterized by wide saucer-shaped valleys that developed under long-term tectonically stable conditions in a tropical climate (Bremer et al., 1981) (Figure 3.1c-d and Figure 3.2). Today most of these valleys are used to dam and store runoff in tanks (Sinhala wewa).

The smooth relief, long-term stable tectonic conditions and and tropical environmental conditions with high chemical weathering rates allowed the development of distinct ‘saprolithic’ layers locally up to several meters thick and covering the bedrock (Bremer et al., 1981). Consequently, outcropping bedrock is a rare phenomenon all over the area. A linear rock outcrop 75-100m in width, 4 km in length and up to 10 m high intersects the area of the ancient city of Anuradhapura from south to north and is builds the most prominent geomorphological feature of the region (Figure 3.1c). In summary, the limited number of outcropping rocks in the area appear as plain rocky surfaces exposed only a few decimeters above the present day surface or as rock boulders with up to 10 m in height and with diameters of up to 8 m. Partly, these boulders appear as small scale basal knobs (German: Grundhöcker after Büdel, 1982), or inselbergs, with their basal part buried in the subsurface (Büdel, 1982). Occasionally, these outcrops built natural rock shelters (Figure 3.3).

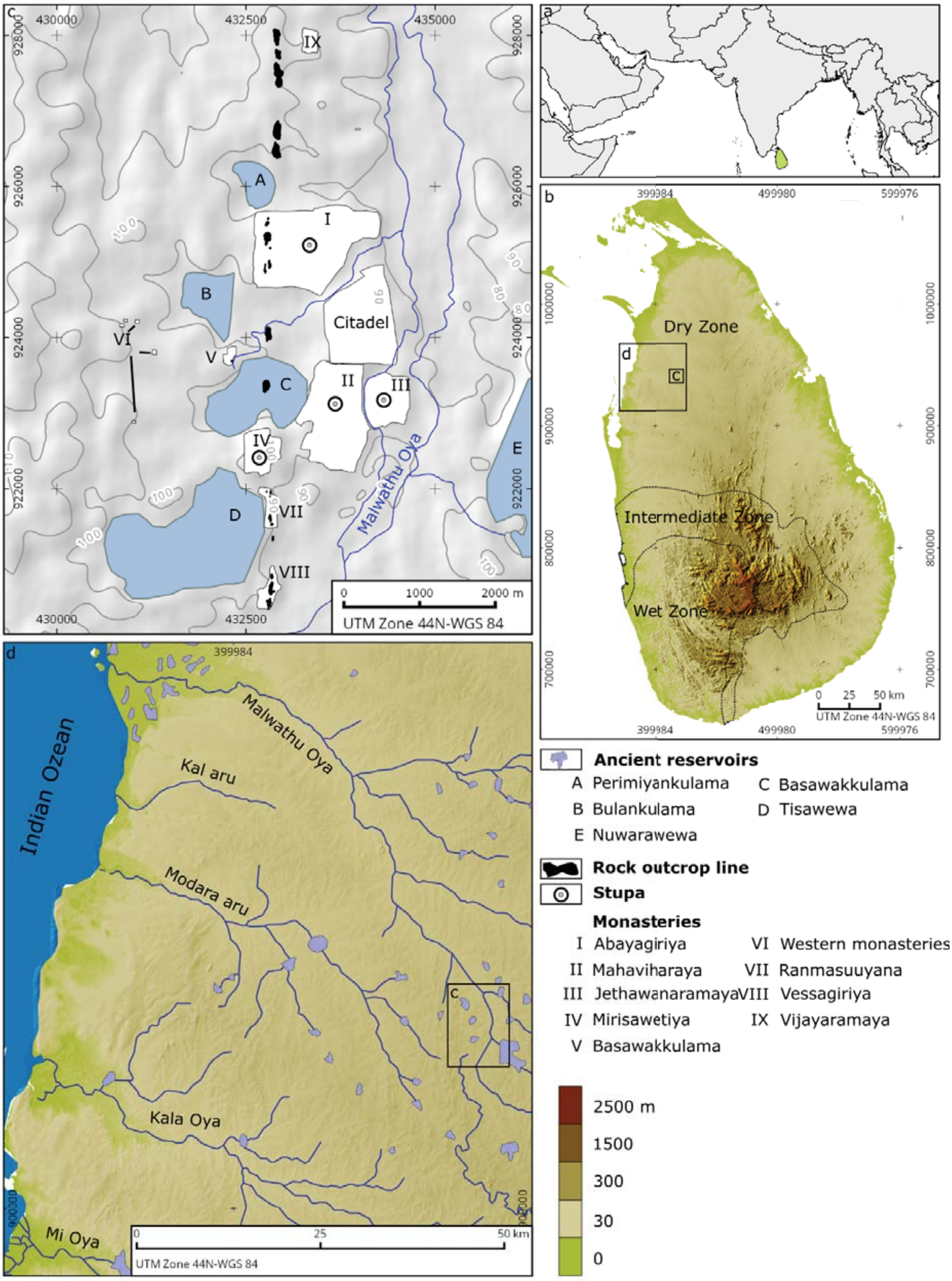

Figure 3.1.: Topography of the study area. (a) Location of Sri Lanka in the Indian Ocean (50°5' E and 90°50' N), (b) the relief of the island and major climatic zones, (c) the topography of the ancient city of Anuradhapura and the structure of the ancient city (d) regional topography with saucer-shaped valleys occupied by ancient reservoirs (Sinhala = Wewa) while the drainage in the region heads west into the Indian Ocean. Elevation data based on Jarvis et al., 2008.

Figure 3.2.: A view of the gently rolling plain of the region with isolated hills, towards the eastern direction of the Anuradhapura city (picture taken from the top of the Ruwanweli stupa (Mahavihara monastery) (see Figure 3.1c). The Jethawanarama stupa is located in the centre of the monastery and Malwathu Oya is flows 200 m to the west of the stupa (see Figure 3.1c). The distance from the Jethawanaramaya monastery (A) to the Mihinthale Buddhist monastery (B) is 28 km.

Figure 3.3.: The outcropping rocks in the ancient city of Anuradhapura frequently appear as (a) rock boulders (approximately up to 10 m in height and 8 m in diameter), (b) plain rocky surfaces (only exposed a few decimeters above the present day surface), and (c) natural rock shelters.

3.2. Climate

Due to its location northwest of the Central Highlands, the area around Anuradhapura is not directly exposed to either the southwest monsoon (May-September) or the northeast monsoon (December-February); consequently, the spatial and temporal rainfall pattern of the area lacks a strong connection to the monsoonal periods (Schütt et al., 2013, 52; Puvaneswaran and Smithson, 1991, 115). Most of the precipitation falls in the inter-monsoonal periods from March to May (minor rainy season) and October to November (major rainy season) (Domroes and Ranatunge, 1993, 741). The annual precipitation of the area averages 1198 mm (1960-1990) (FAOCLIM, 2001). Corresponding to the tropical climate, the temperature regime is characterized by only small variations. The annual average temperature at Anuradhapura totals 27.2°C (1961-90) with highest temperatures to be expected in April to September (average monthly temperature: 28.6°C), while lowest temperatures are reached in November to February (average monthly temperature: 24.6 °C) (FAOCLIM, 2001).

3.3. Geology

Geologically, the island of Sri Lanka corresponds to a terrene and is composed of 90% Precambrian crystalline rocks (Cooray, 1984, 88; Vanacker et al., 2007, 403). The Precambrian basement of Sri Lanka is subdivided into three major regions (Figure 3.4).

The Highland complex forms the central Highland zone and consists of igneous rocks, predominantly granulate faces meta-sediments and Quartzo-feldspathic and charnokitic gneisses (Cooray, 1984, 88). The Highland complex strikes northeast across the central part of the island.

The Wannni complex is located northwest of the Highland complex and forms part of the Lowlands. It consists predominantly of granitic, migmatitic and chanockitic gneiss (Cooray, 1984, 104).

The Vijayan complex is located east and south of the Highland complex and contains a variety of migmatites, gneisses and granitoids; metasediments occur in patches (Cooray, 1984, 104).

Geologically the surroundings of Anuradhapura belong to the Wanni Complex (Figure 3.4a). The Wanni Complex was metamorphosed during the upper amphibolite to granulite facies conditions while the neighboring Highland complex was metamorphosed under the granulite facies conditions (Cooray, 1994, 4; Kröner et al., 1994). Major rock types in the Wanni complex include granites, migmatites, granitoid gneisses, charnockites and metasediments. The common rocks of the area around Anuradhapura are granitic gneiss, migmatitic hornblende biotite gneiss, and charnockitic gneiss. Granitic and charnockitic gneisses are the most pervasive lithologies (Cooray, 1982; Figure 3.4b).

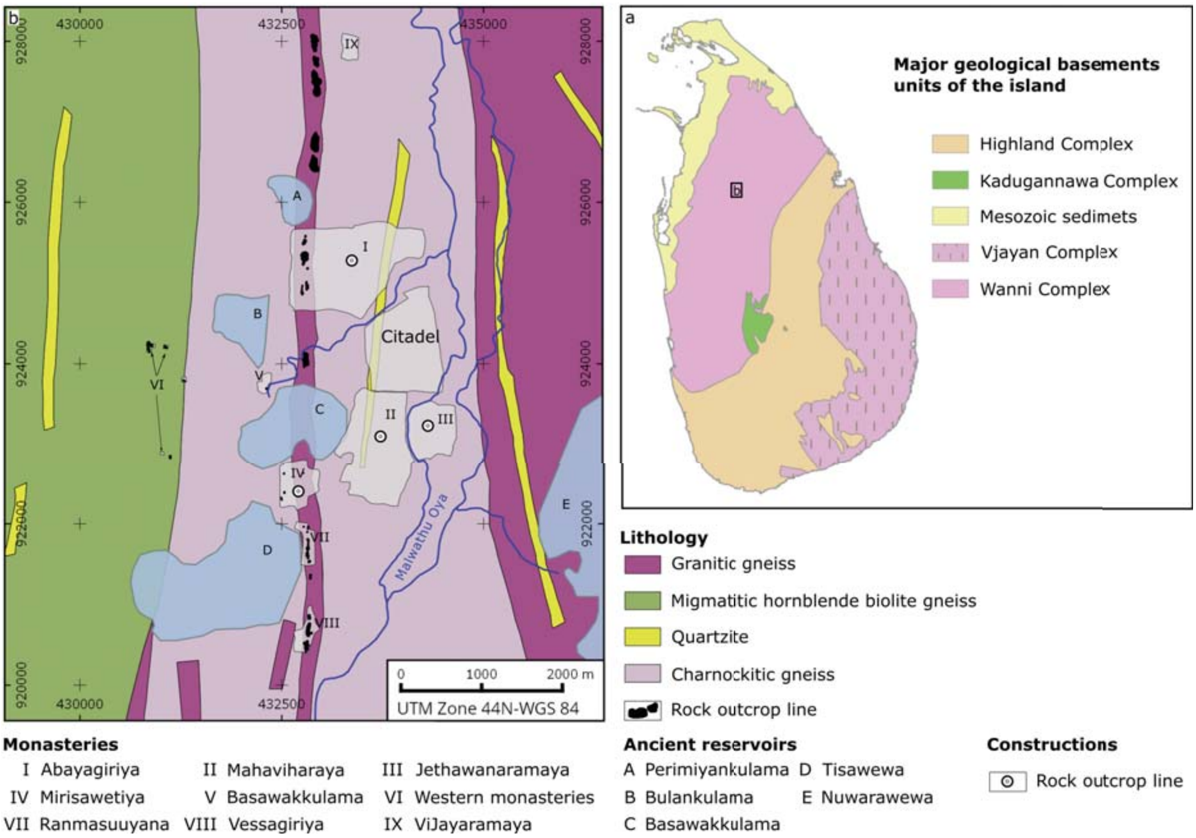

Figure 3.4.: Lithology of the study area. (a) Precambrian crystalline rocks basement of Sri Lanka and its major, minor subdivisions (b) Lithology of the study area and structure of the ancient city of Anuradhapura; Geological basements modified after (Cooray, 1994), regional lithology modified after (GSMB, 1995, 2001, 2009b,a).

CHAPTER 4

Methods

4.1. Fieldwork and sampling

Fieldwork took place in March/April in 2013 and 2014 and in September/October in 2015. In the research area ancient constructions with stone architectural features were documented focusing on their architectural types (building or non-building) and rock types (mineralogical characteristics and textural features). The identification of ancient rock quarries was primarily based on the documentation of ancient quarry marks (Dworakowska, 1975, 98; Heldal and Bloxam, 2008, 127; Klemm and Klemm, 2001, 634). In order to understand subsequent landscape dynamics linked to ancient resource exploitation, (i) the morphology of the outcrops, (ii) the quarry position with respect to the morphology of the outcrop and (iii) the subsequent usage of quarry sites were documented. Furthermore, types of rock textures including foliation and lineation as well as joint patterns of both rocks in the ancient quarry sites and other rock exposures were studied. Fragments detached from the ancient stone constructions due to natural or mechanical degradations were collected as building samples. Source rock samples were collected from ancient quarry sites and marble exposures. All samples were collected with the permission of the Sri Lankan Department of Archaeology.

4.2. Ethnoarchaeological investigation

The ethnographic study is based on the observation and interviewing of a modern stone craftsman who quarries stones using traditional techniques. A rock boulder with a horizontal running foliation plane was chosen for experimental splitting. The ethnographic investigation is based on the assumption of a cultural connectivity or historical relationship between the living and the past culture (Steward, 1942). The interview covered ethnographic elements such as explicit purposes, ethnographic explanations, and ethnographic questions (Spradley, 1979). The ethnographic study followed a series of steps to obtain data, to compare with historical evidence (Table 4.1).

Table 4.1.: Steps followed and focuses used to obtain ethnoarchaeological data

Main Steps	Sub-steps and focuses
Preliminary interview with the craftsman	Personal data of the craftsman (age, place of origin, family situation, how he gained the knowledge Craftsman's experience of stone splitting
Tool preparation	Preparation of charcoal Smithing works Time expenditure
Identification of a suitable splitting location	Selecting rock boulder of proper size Craftsman's knowledge about examineing the foliations in the rock
Splitting task	Chiseling the holes Splitting phase Selection of the tools for different work steps

4.3. Documentation

The entire fieldwork was documented by photographs and field notes. The locations were recorded using a handheld GPS device (Garmin 60CS). Lithological maps at a scale of 1:100,000, published by the Geological Survey and Mines Bureau of Sri Lanka (GSMB, 1995, 2001, 2009b,a) were incorporated to support fieldwork and assist mapping in a GIS environment (QGIS). A digital elevation model (SRTM 3, 90 m* 90 mpixel size) was used to delineate the topography of the island and the study area (Jarvis et al., 2008). The open source graphic software 'Inkscape' (V0.91) was applied for editing maps and drawing sketches.

4.4. Laboratory analysis

All samples were crushed and homogenized using a WIDIA-steal agate swing mill and were dried at 55°C. A portable Analyticon NITON XL3t energy-dispersive X-ray fluorescence spectrometer equipped with a CCD-camera for visual spot control and a semi-conductor detector was used for analyzing the elemental composition of samples (n=61) that originated from bedrock outcrops and ancient stone structures. The cups were mounted on the p-ED-XRF and measured for 120 s with different filters to detect specific elements (see Chapter 7). An internal calibration set had been arranged with fused tablets that were measured with a wavelength dispersive X-Ray fluorescence spectrometer (WD-XRF) against a set of certified reference materials

(CRM; cf Supporting Material). Only those elements that had minimum values four times larger than their 1sigma measurement uncertainty were considered. The wavelength dispersive XRF measurements were conducted at the Institute of Applied Geosciences of the Technische Universität Berlin. A detailed description of the procedure is compiled in the supplementary materials of Chapter 7. The LOI was analyzed according to Dean (1974) and Heiri et al. (2001) at 900 °C in a Thermo Scientific M110 Muffle Furnace.

The mineralogical compounds were examined by X-Ray powder diffraction (XRD) and were determined qualitatively and semi-quantitatively. The powdered samples were analyzed with an RIGAKU Miniflex600 diffractometer at 15 mA/40 kV (Cu kα) from 3° to 80° (2Θ) with an oniometer step velocity of 0.02° 2Θ and 0.5° min–1. The software X-Pert HighScore Version 1.0b by PHILIPS Analytical B.V. was used for difractogram analysis including the correction of program outliers, the elimination of kα2-Peaks, and a calibration to the quartz100 main peak (d = 3.34 Å). The Powder Diffraction Files (PDF) of the ICDD (International Centre for Diffraction Data) were used for identifying the peaks.

Simple descriptive statistics and graphical representations were applied in order to investigate and test whether there are differences between the characteristics of the utilized buildings and source rocks of the investigated area. Computational analyses of the compositional data were conducted using R (Team, 2015) and package compositions (Boogaart et al., 2014).

4.5. Chronology

The chronology of the entire research was arranged according to Deraniyagala (2004).

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CHAPTER 5

Paper 1: Ancient rock quarries in Anuradhapura, Sri Lanka

Abstract

The ancient city of Anuradhapura (4^{th} century BCE–11^{th} century CE), established on the banks of the river Malwathu Oya in north-central Sri Lanka, is one of that country's most important archaeological sites. Numerous ancient buildings and monuments occur throughout the entire settlement. The preserved parts of the Anuradhapura ancient built environment are mostly solid masonry constructions. However, foundations, floor areas, pillars and entrance units of the buildings provide evidence that rock materials were prominently used in constructions. This study focuses on the investigation of former rock quarry locations in the surroundings of Anuradhapura, their distributional pattern and their classification according to their morphological and archaeological significance. The majority of quarrying traces detected in the survey are distributed along a central rock outcrop line which runs across the city area. Altogether, 65 ancient rock quarries were identified in the area and classified into six categories. Moreover, numerous of historic stone buildings in the monasteries are also situated along the exposed rock outcrops line.

Keywords

Ancient quarrying, historic built environment, cultural landscape, natural resources, landscape evolution.

Note

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CHAPTER 6

Paper 2: An ethnoarchaeological study of stone quarrying techniques in historical Anuradhapura

Abstract

Ancient stoneworkers were familiar with different techniques to separate stone blocks from parent rock. Bedrock outcrops with bedded layers, natural foliations or mechanical weathering fractures were preferred starting points for stone quarrying. When such joints did not occur naturally, fractures were created by chiseling holes and inserting wedges, removing bedrock material by channeling or heating the bedrock surface with fire and then imposing pressure on the rock through percussion.

Ancient rock quarries in the surroundings of the ancient city of Anuradhapura, North Central Sri Lanka, provide evidence of the extensive utilization of the chiseled holes and wedge quarrying technique for the splitting of stone blocks. This quarrying technique is mainly based on the creation of a series of holes along the margin of the block to be separated. After separation, these holes frequently appear as half-holes in the parent rock and are mirrored on the separated blocks. With respect to archaeological monuments in the ancient city of Anuradhapura, stone was extensively utilized as a construction material.

This ethnoarchaeological investigation explores the precise working procedure related to the chiseled holes and wedge quarrying technique, and aims to identify the kinds of tools used and to estimate the time necessary for one splitting attempt. The workflow of a stone craftsman still applying traditional techniques of quarrying was observed. This craftsman used cylinder-shaped iron chisels to bore oval-shaped holes into the parent rock. Flat wedges and iron feathers were used to create a fracture line along the holes. The oval holes result predominantly in controlled straight fracture lines, which connect the holes in the intended way. It required approximately

2.5 hours to separate a 50 cm by 120 cm by 40 cm block from the parent rock using this technique.

Keywords

Ancient quarrying, chiseled quarry holes, wedges, smithing works, foliation plane, experimental archaeology.

Note

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CHAPTER 7

Paper 3: The significance of stone resources in the cultural landscape of ancient Anuradhapura (377 BCE – 1017 CE), Sri Lanka

Abstract

The city of Anuradhapura, founded on the banks of the River Malwathu Oya, was the ancient capital of Sri Lanka between the 4^{th} century BCE and the 11^{th} century CE. The widespread architectural remains of the ancient city make it the most important archaeological site in the cultural landscape of the country. Most of the foundations, floor areas, pillars, and entrance units of the ancient constructions consist of stone materials, evidencing that stones were the principal building material in the ancient Kingdom of Anuradhapura. Numerous ancient rock quarries are located inside and outside the ancient city complex; most of them can be found along a striking N-S line of rock outcrop that runs through the historic city. This study focuses on the importance of the availability of stone resources for the founding and development of early Anuradhapura settlement. For this purpose the building rocks in the ancient constructions are analyzed and the spatial distribution of their source areas examined using the petrological, chemical and mineralogical charecterization of both building and source rock specimens. The investigations document the availability of gneissic bedrock naturally accessible in outcrops. This was an important factor which stimulated the development of the capital out of the manifold initial settlements that were founded, as in the whole area outcropping bedrock is rare. Moreover, it is shown that the quarry sites of gneisses used for construction of the monastic buildings were located in the city, while marble rocks used for ornamentation were imported.

Keywords

Petrography, stone architecture, sacred buildings, ornamental rocks, quarrying, locational factors

7.1. Introduction

The ancient city of Anuradhapura existed as the capital of the Sri Lankan kingdom in north-central Sri Lanka from the 4^{th} century BCE to the 11^{th} century CE. The comprehensive architectural remains of Anuradhapura make it one of the most important archaeological sites in the cultural landscape of Sri Lanka. Even today, the ruins of sacred and residential constructions are evidence of the outstanding architectural and artistic culture that existed during the Anuradhapura period (Bandaranayake, 1974, 7).

The ancient architecture of Anuradhapura is characterized by a mixed material tradition that used parallel burnt bricks, timber and stones (Bandaranayake, 1974, 375). However, the majority of foundations, floor areas, pillars, and entrance units of the buildings consist of stone blocks and provide evidence that rocks were the primary building material used for the construction of monumental buildings or elements during the Anuradhapura period. Gneissic rocks were the preferred building material in the ancient built environment of Anuradhapura.

Topographically, the ancient city of Anuradhapura is located in a gently rolling plain. To the east of the city, the river of Malwathu Oya flows in a northerly direction. The basement rock of the area is dominated by metamorphic rocks (Kröner et al., 1994; Cooray, 1995, 4). However, superficial rock exposures are rare in the area due to a thick saprolite cover (Ball and Herbert, 1992; Schütt et al., 2013). The few rock exposures in the area occur west of the city along a linear outcrop, which runs from south to north. The majority of ancient architectural features, the Citadel as the fortified center of the ancient city, and he majority of ancient monasteries were situated between the Malwathu Oya river and the rock outcrop line (Figure 3).

While today the architectural remains of Anuradhapura still provide an impressive image of the wealthiness and the technical know-how of its residents and kings, it is still unclear why Anuradhapura was founded in the midst of the lowland, several days' journey from the coast. The following research will focus on the analysis of the availability of construction rocks as an indispensable requirement for the construction of monuments. For this purpose the building rocks of the ancient constructions will be investigated and the spatial distribution of their source areas examined using the petrological, chemical and mineralogical characterization of both building and source rock specimens. To achieve a complete picture it will be necessary to evaluate whether additional locational factors play a vital role in explaining the foundation of Anuradhapura where it is today – in the midst of the north-central lowlands.

7.2. State of the art

7.2.1. Foundation of early settlements with reference to the availability of construction material

Factors controlling the decision to establish a permanent settlement are often related to environmental characteristics (Renfrew and Bahn, 2012, 223). Since prehistory building materials, arable and grazing land, water and fuel have been regarded as the major natural resources required to found a settlement (Chisholm, 2007, 115). Various archaeological studies clearly document that the local availability of a specific building material played a significant role as a locational factor for the foundation of permanent settlements (Abu Jaber et al., 2009; Bullard, 1960; Degryse et al., 2009).

During the Early Iron Age, people tended to locate Megalithic burials in the vicinity of bedrock source areas where stone slabs for the construction of burial monuments could be easily extracted, thus avoiding the necessity of transporting the heavy material (Schierhold, 2009; Seneviratne, 1984). Evidence for the Early Iron Age quarrying of lithic materials for the construction of burial plots close to bedrock exposures has been found, for instance for sites in Germany (Schierhold, 2009, 41), Ethiopia (Hagos, 2001), Mongolia (Allard and Erdenebaatar, 2005) and Sri Lanka (Weisshaar, 2004, 106).

In addition, the location of ancient settlements and sacred monuments also indicates the importance of the local availability of construction materials. The temples of Athena and Apollo (6^{th} century BCE) in the ancient city of Karthaia, Greece provide evidence that ancient settlers extracted construction materials in the direct vicinity of the temples. The preserved evidence of quarrying (chisel marks), located on the north side of the temple of Apollo and the southern part of the foundation of the temple of Athena, illustrates that they were built directly on the quarry face (Kolaiti et al., 1992, 29). In ancient Egypt, the primary constructional features of the temples, pyramids, and tombs were built from stone materials extracted near to the construction sites (Klemm and Klemm, 2001, 631). The ancient Roman cities of Gearasa (most buildings date to the 1^{st} and 2^{nd} century CE) in Jordan (Abu Jaber et al., 2009, 67) and Hellenistic-Roman city Sagalassos (main building activities from the 4^{th} century BCE to the 3^{rd} century CE) in Turkey (Degryse et al., 2009) also demonstrate the attraction of local stone sources in the immediate vicinity of the city. In India, the ruins in the ancient capital of Rajagiha (modern Rajgir) dating to the Early Historical Period of Buddhist and even pre-Buddhist architecture (600 - 500 BCE) reveal that they were constructed with locally available stones (Chakrabarti, 1976, 263). The ancient Indian Buddhist rock-cut cave temples of Ajantha (2^{nd} century BCE - 6^{th} century CE) (Burgess, 1970, 67) and Ellora (6^{th} century CE) (Malandra, 1988, 148) were also pragmatically established based on the availability of rock exposures. Some of the Maya ruins in northeastern Peten, Guatemala (classical period of Maya culture, 3^{rd} - 9^{th} century CE) reveal that these settlements were founded according to the availability of water supplies and suitable areas for housing sites, focusing on well-drained, level ground where the bedrock occurred close to the surface in order to dig the chambers known as "Chultuns" into the bedrock (Bullard, 1960, 326).

7.2.2. The advantage of gneiss rocks in ancient architecture

Different kinds of bedrock were used as construction materials by early civilizations. The attraction of a particular type of bedrock was determined by its availability, structural properties (strength and durability) or aesthetic qualities (such as colour and surface) (Tucci, 2014, 246). Common varieties of bedrock used as construction materials were marble, limestone, sandstone, basalt and gneisses (Bullard, 1960; Kolaiti et al., 1992; Burgess, 1970; Malandra, 1988). Gneissic rocks were frequently preferred due to their hardness (Awan, 2008, 110; Clarke, 1916, 170; Ghosh, 1990, 15). Taking into acount the load-bearing function of the constructions, many ancient architects frequently used medium- to fine-grained gneissic rocks (Ghosh, 1990, 15; Harrell, 2013, 4; Howe, 2016, 78; Ratnayake and Pitawala, 2009, 1026). Generally, as a result of metamorphism, gneissic rocks feature clearly developed parallel foliations and well-developed rock joints (Cooray, 1984, 26; Miyashiro, 2012, 31; Nicholson and Shaw, 2000, 32), which ease the workflow of stone harvesting (Heldal, 2009, 89).

Historical examples of gneissic rock constructions provide evidence that these materials were primarily used in basal structures, pillars or for the construction of walls (Bugini and Folli, 2008, 39; Dunkley, 1936, 176; Hellström, 1991, 300). In Anuradhapura gneissic rocks were also preferentially utilized for the construction of structures such as pillars, stairs, balustrades and foundations (Brown, 2013, xxxiv; Katupotha, 2014, 328; Ratnayake and Pitawala, 2009, 1026).

7.3. Study area

7.3.1. Natural character

The city of Anuradhapura is located in the north-central lowlands of Sri Lanka (8°21' N, 80°23' E; 89 m asl). Geologically, 90% of Sri Lanka's bedrock is formed by Precambrian crystalline rocks, built during granulite and amphibolite facies metamorphism (Cooray, 1995) in the early Palaeozoic (Hiroi et al., 1994). Based on age, metamorphic grade, and structural features, the metamorphic bedrock of Sri Lanka is subdivided into four main complexes: the Highland Complex, Wanni Complex, Vijayan Complex and Kadugannawa Complex (Cooray, 1994, 7; Kröner et al., 2013, 2) (Figure 7.1b). The area around Anuradhapura is located in the Wanni Complex (Figure 7.1b), which is composed of granites, migmatites, granitoid gneisses, charnockites and metasediments as major rock types (Cooray, 1994, 4). The study area is characterized by granitic gneiss, migmatitic hornblende biotite gneiss, and charnockitic gneiss with meta-sedimentary rocks such as quartzite (Figure 7.1a). While granitic gneiss outcrops are located along a striking N-S line of rock outcrop that passes the ancient city of Anuradhapura, the nearest marble outcrops are located in the village of Kanadarawa, 12 km northeast of Anuradhapura, and the village of Medagama, 42 km to the south (GSMB, 2009a; GSMB, 2001) (Figure 7.1b; figure 7.5a).

The topography of the area around Anuradhapura is flat, except for some isolated hills (inselbergs) which rise above the gently rolling plain (Figure 7.2b). The land surface rises from west to east. Consequently, the Malwathu Oya, Modaragam Aru and Kala Oya, as the region's major rivers, drain westwards into the Indian Ocean (Figure 7.5a). Valleys, especially of the low-order tributaries, are wide and saucer shaped, having developed under long-term tectonically stable conditions in a tropical climate (Bremer et al., 1981). Many such valleys have been used since ancient times to dam runoff and store it in tanks (Wewa or Kulama in Sinhala).

Intensive chemical weathering under tropical environmental conditions caused the development of a saprolite layer up to several meters thick overlying the bedrock (Schütt et al., 2013, 66). Consequently, outcropping bedrock is a rare phenomenon all over the region. An exception is the up-to-30 m elevated linear rock outcrop which intersects the ancient city of Anuradhapura from south to north over a distance of c. 4 km and which has a width of 75-100 m. This line builds the most prominent geomorphological feature of the region due to its elevated character (Figure 7.2a).

The climate at Anuradhapura is tropical with an average temperature of 27.1 °C and annual precipitation of 1198 mm (FAOCLIM, 2001). Due to the location of Anuradhapura north of the central highlands of Sri Lanka, which function as an orographic barrier, only a small amount of annual rainfall results from the southwest monsoon (May-September) and northeast monsoon (December-February) (Puvaneswaran and Smithson, 1991, 115; Schütt et al., 2013, 52). The majority of annual rainfall occurs in the inter-monsoonal periods during a short rainy season from March to May and a main rainy season from October to November (Domroes and Ranatunge, 1993).

7.3.2. Past and present land use

Rice cultivation represents the main present-day land use in the Anuradhapura region (Bandara, 2003). The rice is predominantly cropped in lower topographic positions or on the alluvial soils (Gilliland et al., 2013). Shifting cultivation, locally known as "Chena cultivation" (Dharmasena, 1994; Silva, 1977) is frequently applied on the upper slopes, close to the divides (Gilliland et al., 2013). The earliest trace of rice consumption in Anuradhapura has been found for the Early Iron Age (900 - 600 BCE) (Deraniyagala, 1972) (Table 7.1). According to inscriptional evidence, the land-use pattern in ancient Anuradhapura was characterized by rice cultivation intertwined with other crops that were less dependent on the availability of water (Paranavithana, 2001, 219).

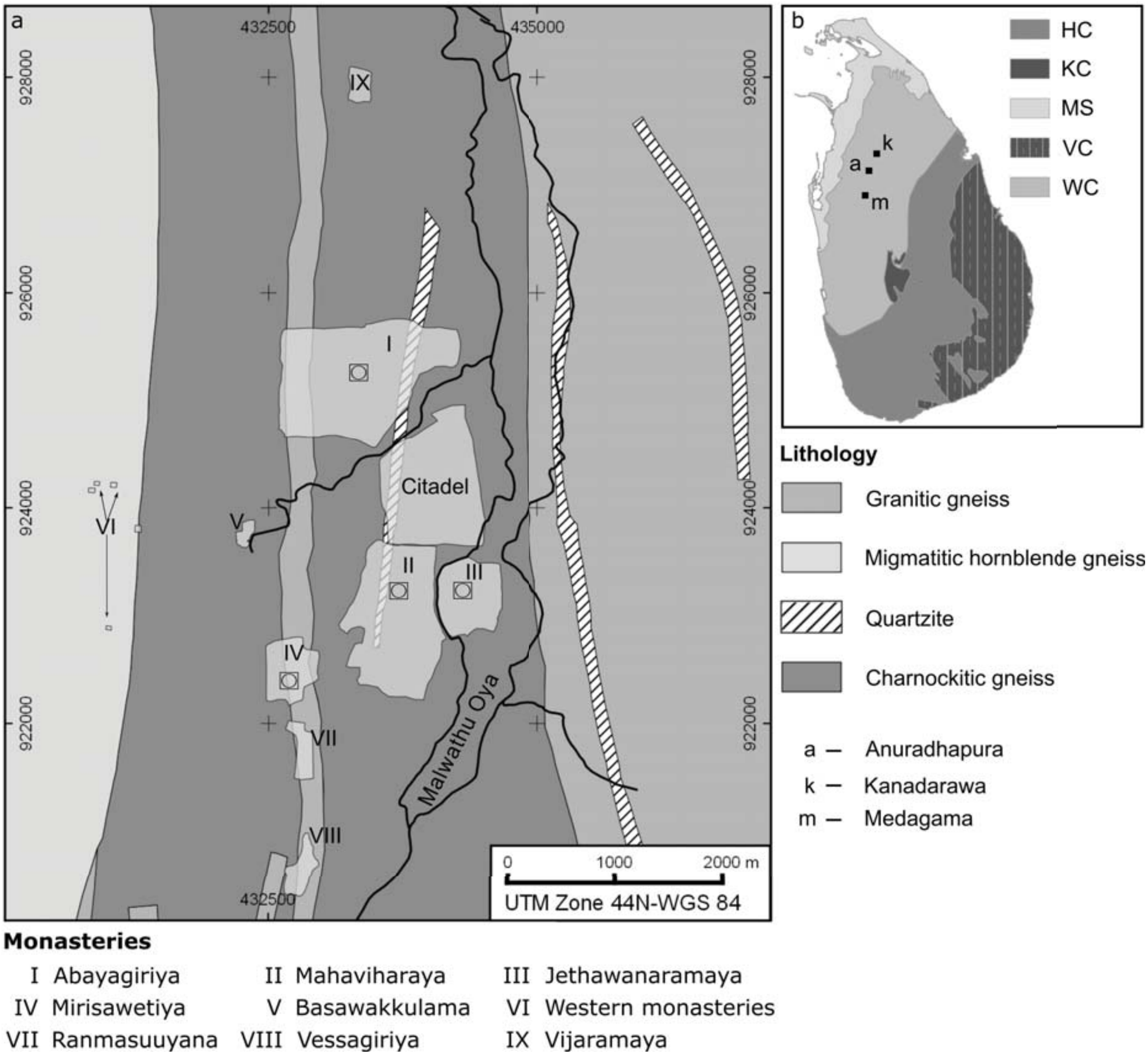

Figure 7.1.: The lithological character of Sri Lanka and the Anuradhapura area. (a) Location of Anuradhapura within the geological complexes of the island (HC - Highland Complex, KC - Kadugannawa Complex, MS - Miocene Sediment, VC - Vijayan Complex and WC - Wanni Complex) and (b) study area with its regional lithology and locations of ancient Buddhist monastic complexes in the ancient city area of Anuradhapura; (lithological regions based on GSMB, 1995, 2001, 2009b,a)

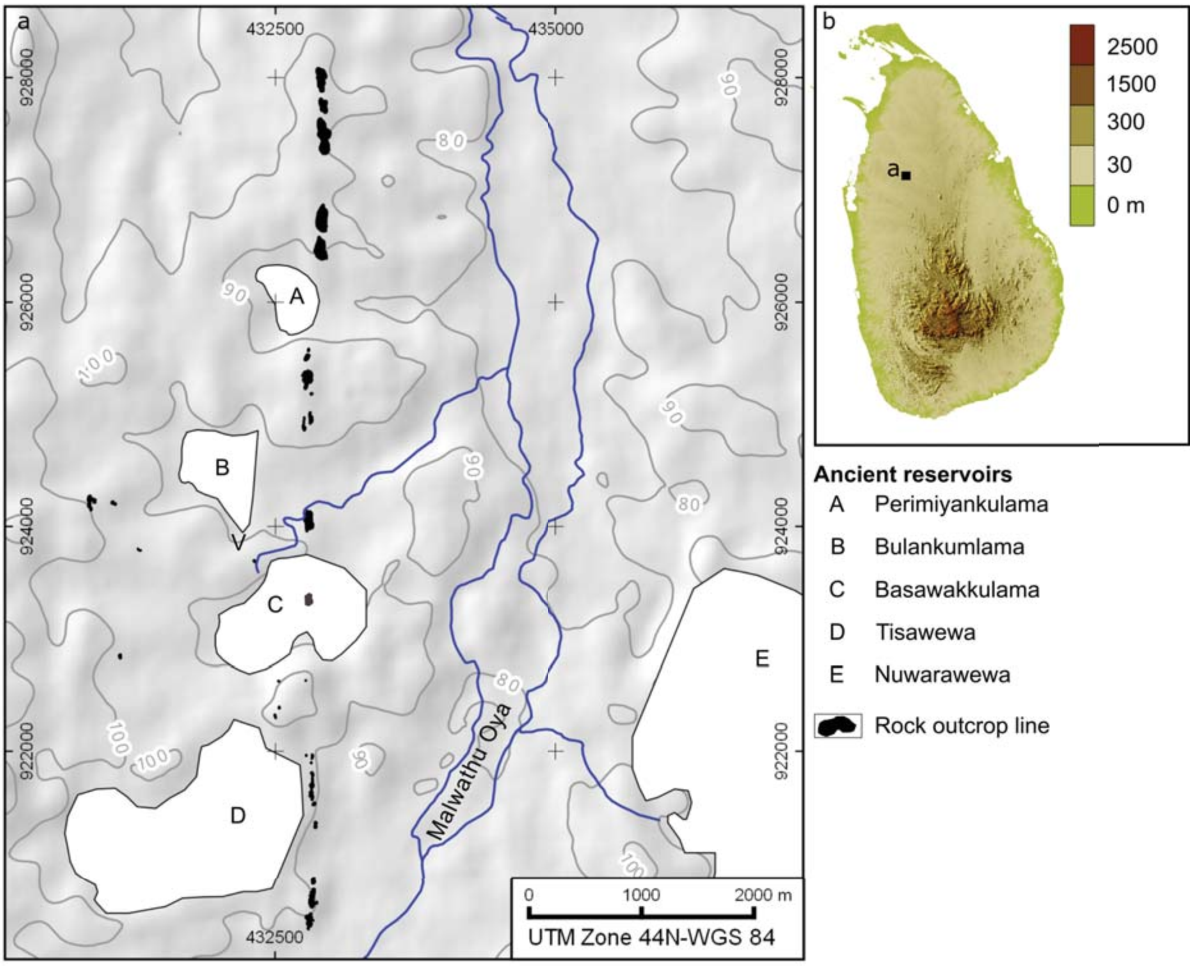

Figure 7.2.: Relief of Sri Lanka and the study area (a) Relief of Sri Lanka, (b) Topography of the ancient city of Anuradhapura, with the Citadel, monasteries and ancient reservoirs (locally wewa or tank). Elevation data based on (Jarvis et al., 2008)

7.3.3. Settlement history

Numerous excavations in the area of the ancient city of Anuradhapura have yielded information on the formation of a first permanent human settlement during the Early Iron Age (900 - 600 BCE) (Deraniyagala, 2004b, 709). For this period traces of iron technology, pottery, domestic cattle and horses as well as paddy cultivation have been documented (Table 7.1) (Coningham, 1999, 5; Deraniyagala, 2004b, 709). At 800 BCE the area of the Early Iron Age settlement exceeded c. 10 hectares and grew until 700 - 600 BCE to an area of 50 hectares (Coningham, 1999, 127; Deraniyagala, 2004b, 709).

The Basal Early Historic period of Anuradhapura (600 - 500 BCE) (Table 7.1) corresponds to the time when the traditional history of Anuradhapura begins. During this period, evidence of writing appeared for the first time in Sri Lankan history (Table 7.1). The initial urbanization of Anuradhapura began during the Lower Early Historical period (500 - 250 BCE) (Deraniyagala, 2004b, 712) (Table 7.1), coinciding with the arrival of Buddhism (c. 300 BCE) (Bandaranayake, 1974, 11; Cave, 1907, 34; Mahavamsa, 1912, 91). According to the Mahavamsa description, King Pandukabaya (reign: 437-367 BCE) developed the rural settlement known as 'Anuradhagama' to the capital of the Anuradhapura kingdom (Mahavamsa, 1912, 73).

From the beginning of the Mid Early Historical period (Table 7.1), the administrative mechanism of the city became more refined and Anuradhapura extended its sovereignty over the entire hinterland (De Silva, 2000; Mendis and Weerasekara, 2013). During this period, the city rapidly developed its various residential and religious sectors (Citadel, major and minor monasteries), including some small reservoirs and agricultural areas (Cave, 1907, 35; Seneviratne, 1994, 24; Seneviratne, 1987). The Upper Early Historical epoch (100-300 BCE) is regarded as the period of growth; parallel to demographic expansion, large-scale settlements developed with water supply systems based on major reservoirs (Seneviratne, 1984). Imported ceramics from northern India to the Mediterranean region illustrate the supra-regional importance of the city at this time (Coningham, 2006, 5; Coningham, 1999, 126; Deraniyagala, 2004b, 718) (Table 7.1). Furthermore, Anuradhapura is regarded as one of South Asia's major sites of pilgrimage, attracting merchants from all over the Indian Ocean (Coningham, 2006; Coningham, 1999). After the invasion by South Indians in 1077 CE (Chulawamsa, 1953, lviii) Anuradhapura collapsed and a new kingdom was established with a capital in Polonnaruwa.

Table 7.1.: Cultural sequence and material evidence of ancient settlers in Anuradhapura after Deraniyagala 2004; Deraniyagala 1972; Coningham 1999; Coningham 2006; Senevirathe 1987; Seneviratna 1994; Cave 1907; Mahavamsa 1912

Cultural sequence	Time	Occurrences
Early Iron Age	900-600 BCE	Iron, horse, domestic cattle, paddy cultivation, wattle and daub constructions, wheel-made pottery
Basal Early Historic period	600-500 BCE	Iron, cattle, horse, roofing tile, wheel-made pottery, Early Brahmi (Writings), arrival of Vijaya
Lower Early Historic period	500-250 BCE	Important ceramics, higher technological roofing tile, iron, burnt bricks, minor irrigations, using rock shelters as living places
Mid Early Historic period	250-0 BCE	Important ceramics, higher technological roofing tile, iron, burnt bricks, coins, glass, first large tanks
Upper Early Historic period	0-300 BCE	Coins (local) and Indo-Roman, decorated building stone, important ceramics, major and minor monasteries, buildings with whitewashed walls, massive irrigations systems, extended sovereignty the hinterlands
Middle History	300-1250 BCE	

7.3.4. Ancient architecture of Anuradhapura

The preserved floors of residential and workplace wattle-and-daub constructions represent the earliest architecture of Anuradhapura, dating from the Early Iron Age (Coningham, 2006, 5; Coningham, 1999, 129) (Table 7.1). After the arrival of Buddhism, natural rock shelters were frequently utilized as the dwelling places of Buddhist monks (Mahavamsa, 1912, 112), easy to recognize due to the drip ledges created over the roof portal, which controlled rainwater trickling into the rock shelter (Bandaranayake, 1974, 46; Coningham, 1995, 229). Later examples of rock shelters illustrate that brick masonry walls with doors and windows covered their entrances (Bandaranayake, 1974, 259; Coningham, 1995).

According to the archaeological evidence, burned bricks were the main construction material in use until the Lower Early Historical period in Anuradhapura (Deraniyagala, 2004a, 712; Deraniyagala, 1972, 58) (Table 7.1). As the archaeological evidence reveals, and written chronicles (especially the Mahavamsa) describe, the utilization of stone blocks as construction materials did not start before the Mid Early Historic period (Coningham, 2006, 5; Coningham, 1999, 126-129; Deraniyagala, 2004b, 719).

Most of the preserved building structures in the ancient monasteries of Anuradhapura were probably constructed after the 5^{th} century BCE (Bandaranayake, 1974, 7). The lost structures of the upper floors, especially the roofs and upper walls, probably consisted of perishable materials, mainly timber (Bandaranayake, 1974, 15; Ranaweera, 2013, xxi). However, stone materials are the major architectural feature of both buildings and non-building structures in Anuradhapura. In Anuradhapura stone blocks were predominantly integrated in the foundations, platforms, floor areas, and pillars of sacred and residential buildings (Brown, 2013, p. chapter xxxiv). In non-building architectural features stone materials were utilized for irrigational constructions, sculptures, ancient bridges and ramparts (Coningham et al., 2007, 705; Schroeder, 1990; Shannon and Manawadu, 2007, 12).

The majority of the ancient quarries are situated along the central rock outcrop line which intersects the area around Anuradhapura in a N-S direction. The quarries along the rock outcrop are mostly located (i) at boulders exposed on the surface (at the side or on the top), (ii) directly at surface level, or (iii) associated with the rock shelters. Further quarries are found at the bottoms of the Basawakkulama tank and Tisawewa tank. Pit quarries are located west of the city where the migmatitic hornblende gneiss occurs below the saprolithic layer; the Western monasteries were built close to these quarry pits (Wagalawatta et al., 2015, 55).

7.4. Material and methods

7.4.1. Field work and data recording

During field investigations (March and April in 2013, 2014), monasteries and habitation sites with ancient stone constructions (Figure 4), ancient quarries and natural outcropping rocks as well as ancient reservoirs were systematically identified and surveyed. The petrological characteristics of building and source rocks were macroscopically described, focusing on their dominant structural and textural features and mineral composition.

Samples collected from the ancient buildings are fragments detached as results of natural and mechanical degradation (gneisses n=28, marbles n=10). Collected source rock samples originate from ancient quarry sites and natural rock exposures (gneisses n=19, marbles n=4) (Figure 7.5a, b). All samples were collected with the permission of the Department of Archaeology, Sri Lanka.

The entire fieldwork was documented with photographs. The locations were recorded using a handheld GPS device (Garmin 60CS). Lithological maps at a scale of 1:100,000 (GSMB, 2009a, 2009b, 2001, 1995) were incorporated to support the fieldwork. A digital elevation model (SRTM 3; 90m*90m pixel size) was used to delineate the topography of the study area.

7.4.2. Laboratory analysis

A portable Analyticon NITON XL3t energy-dispersive X-ray fluorescence spectrometer equipped with a CCD-camera for visual spot control and a semi-conductor detector was applied to analyze the elemental composition of samples. All samples were homogenized using a WIDIA-steel agate swing mill and kept dry at 55 °C. For analysis we placed 4 g of the homogenized sample into a plastic cup and sealed it with a mylar foil (0.4 µm). The cups were mounted on the p-ED-XRF and measured for 120 s with different filters to detect specific elements (Table 7.7). The p-ED-XRF was calibrated using the internal reference material (IRM; cf. supplementary data-), calibration was re-checked with the IRM every 12 measurements. The LOI was analyzed according to Heiri et al. (2001) at 900 °C in a Thermo Scientific M110 Muffle Furnace. The standard material used for calibration results from 12 representative samples from local gneiss and marble. The chemical composition of these samples was analyzed with a wavelength dispersive XRF at the Institute of Applied Geosciences of the Technische Universität Berlin (see supplementary data).

Only elements with mean values four times larger than their 1α measurement error were considered for further data analysis. The contents of the traces Ba, Zr, Sr, Rb, Zn, Co, V are given in ppm, the contents of the major components SiO_2, Al_2O_3, Fe_2O_3, CaO, K_2O, P_2O_5 and TiO_2 are calculated as oxides and are given in mass-%.

Simple descriptive statistics and graphical representations were applied to investigate differences between the characteristics of the samples originating from constructions and the bedrock in the vicinity of the investigated monuments. p-ED-XRF data (Table 7.2, 7.3) are scaled following Aitchison Geometry to an Aitchison composition scale, in order to honor the characteristics of a compositional dataset, i.e. scaling, perturbation, and permutation invariance as well as subcompositional coherence (Boogaart et al., 2014, 33). Computational analyses of the compositional data were conducted using the compositions-package (Boogaart et al., 2014) in (Team, 2015).

The qualitative and semi-quantitative mineralogical compounds were examined by X-Ray powder diffraction (XRD). The powdered samples were analyzed using a RIGAKU Miniflex600 diffractometer at 15 mA/40 kV (Cu kα) from 3° to 80° (2Θ) with a goniometer step velocity of 0.02° steps and 0.5° min–1. The software X-Pert HighScore Version 1.0b by PHILIPS Analytical B.V. was used for difractogram analysis. Within this program outliers were corrected, the kα2 peaks were eliminated, and a calibration to the quartz100 main peak (d = 3.34Å) was applied. The Powder Diffraction Files (PDF) of the ICDD (International Centre for Diffraction Data) were used for identifying the peaks.

7.5. Results

7.5.1. Stone architecture and outcropping rocks

In the ancient city of Anuradhapura it was possible to identify 478 ancient building and non-building structures (e.g. channels, ramparts, wavebreakers of tanks, etc.) that had been constructed utilizing stone blocks. There are 456 ancient constructions with gneiss while marble is found in 22 constructions (Figure 7.3). The gneiss was predominantly utilized in the foundations, pillars, and staircases of the ancient buildings, as well as for constructions of ramparts, wavebreakers, channels, ponds, and bridges (Figure 7.4a, d). Marble was rarely used in the ancient built environment but predominantly occurs in highly sacred Buddhist constructions such as Buddha image houses, stupas, Bodhi tree shrine (Bodhigara in Sinhala), Buddha statues and footprints of Buddha (Figure 7.4b, c).

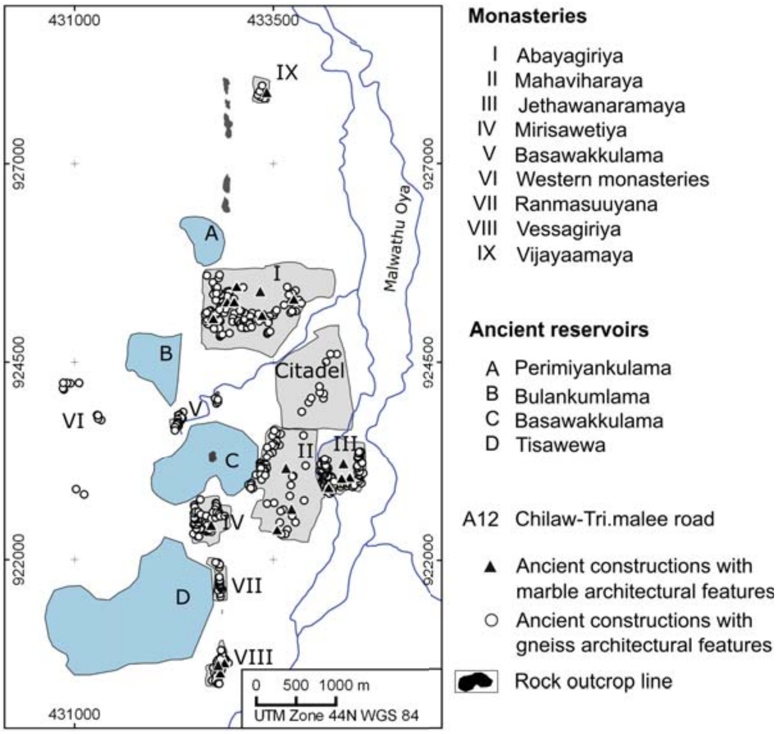

Figure 7.3.: Spatial distribution of ancient constructions

7.5.2. Petrological character

The Western monasteries in the ancient city of Anuradhapura are located on the migmatitic hornblende gneiss zone; architectural features in this area are frequently constructed using migmatites hornblende gneiss (Figure 7.1a; Figure 7.4d, e). The central parts of the city are founded on Charnockitic gneises, and the stone architectural features of the ancient buildings are mostly constructed of granitic gneiss, which is exposed along the line of rock outcrop.

Gneissic rock exposures were frequently identified as ancient quarries. A strongly developed joint system trending in a N-S direction predominates in the gneissic rocks. In addition, joints trending in an E-W direction with vertical dipping occur locally. Traces of quarry sites and separated blocks indicate that local rock exposures were frequently exploited for ancient quarrying operations (Figure 7.6). The gneissic rocks utilized as a construction material in ancient Anuradhapura are characterized by fine- to medium-grained rocks; small patches with coarse-grained quartz and feldspar are found locally. The gneissic rocks are made up of quartz, K-feldspar, and plagioclase. Mafic minerals such as biotite and hornblende occur with minor amounts and are highly variable. The textural features of the rocks originating from the ancient quarries are similar to those of the rocks found in buildings and other constructions. The marbles used as construction material are predominantly composed of carbonates and have minor diopside, phologophite, muscovite, and olivine contents. The size of the minerals varies from fine to very coarse.

Figure 7.4.: Stone-made structures in the ancient city of Anuradhapura. (a) Restored monastic building with stone-made foundation, door and window frames, guard stones and balustrades in Abayagiriya monastery. (b) Ancient Bodhi tree shrine decorated with marble stones in the Abayagiriya monastery. (c) Marble sculptures (ancient Buddha statues in the restored temple of Ruwanweliseya in the Mahavihara monastery). (d, e) Migmatitic hornblende gneiss pillars were used in the entrance of a double-platform monument in the Western monasteries.; photographs taken by Wagalawatta 2015.

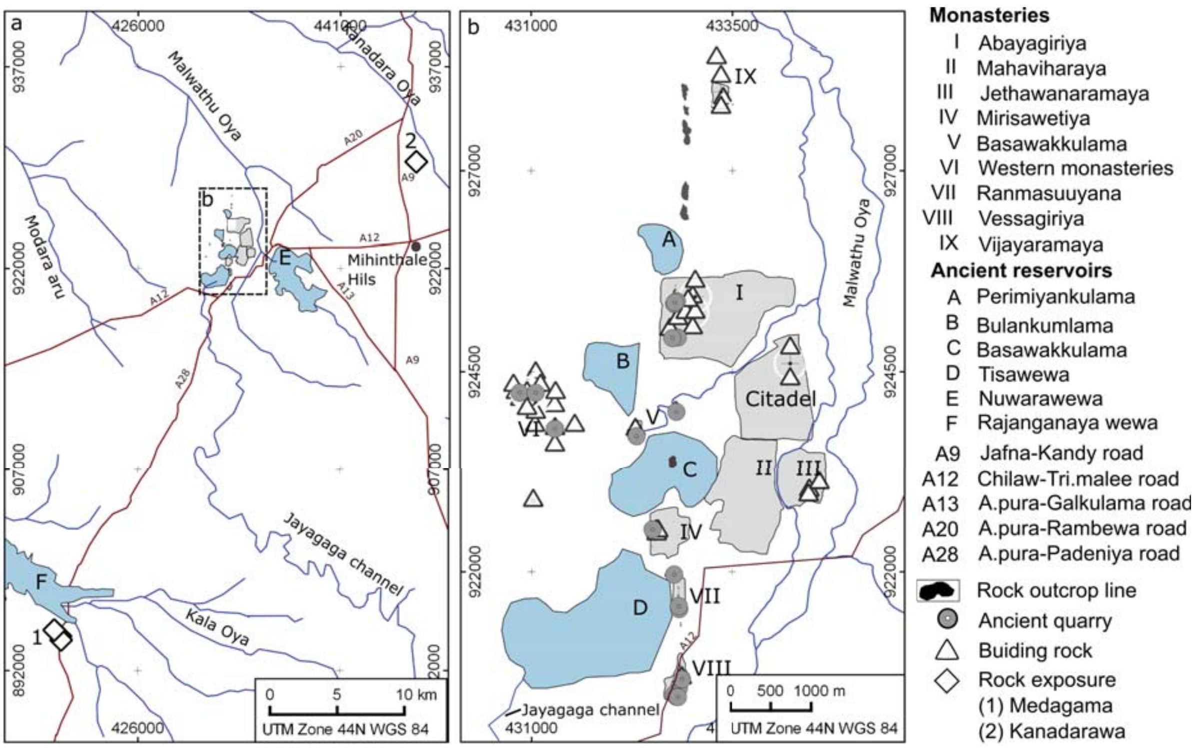

Figure 7.5.: Locations of the origins of building and source rock samples. (a) The hinterland of Anuradhapura and the nearest marble outcrop to the ancient Anuradhapura city (b) Locations of the building and source rock samples in the city.

Figure 7.6.: Available quarrying evidence in the rock structures. (a) A boulder with well-developed foliations in the Abayagiriya monastery. It also illustrates that ancient stonecutters attempted to quarry stone pieces following the foliation plains, which dip left to right. (b) The rock-cut cave located in the Abayagiriya monastery. This is an obvious example where ancient stoneworkers quarried a certain amount of building materials creating a cave. The red arrow points to a rock joint gently dipping inwards to the parent rock. The cave's face also dips in the same direction, as it was created through the rock joint. (c, d, e) Foliation plains occur on the separated stone blocks. They illustrate that ancient quarrymen quarried the blocks following parallel foliations.

7.5.3. Chemical characteristics of the rocks

For the granitic gneiss samples the sum of detected oxides and the LOI totals average 94.134 mass-% (SD=3.288, n=47) for the building rock samples and 94.567 mass-% for the bedrock samples (SD=2.783, n=27; (Table 7.2). Granitic gneiss samples are mainly composed of SiO_2 averaging 74.246 mass-% in samples from building rock samples (SD=3.168, n=47) and 74.046 mass-% in samples from source rocks (SD=2.315, n=27). Contents of Al_2O_3 average 11.051 mass-% in building rock samples (SD=0.717, n=47) and 11.256 mass-% in source rock samples (SD=0.740, n=27). Potassium has the character of a minor component reaching average K_2O

contents of 5.022 mass-% in building rock samples (SD=0.974, n=47) and 4.956 mass-% in source rock samples (SD=1.391, n=27). The average Fe_2O_3 contents total 1.898 mass-% in the building rock samples (SD=1.041, n=47) and 2.081 mass-% in the source rock samples (SD=0.664, n=27). The mean residual of the remaining major oxides sums up to <2 mass-% for each analyzed sample category. The mean values for the LOI at 900°C are 0.424 mass-% in building rock samples (SD=0.149, n=47) and 0.601 mass-% in source rock samples (SD=0.359, n=27). Barium, zircon, strontium, rubidium, zinc, cobald and vanadium were detected in traces in all the gneissic rock samples analyzed.

Characterized by lower SiO_2 and K_2O contents and higher contents of TiO_2, Al_2O_3, Fe_2O_3, and CaO, the migmatitic hornblend gneiss samples (n=2) can be clearly differentiated from the granitic gneiss samples (α<0.05). Marble bedrock samples show an average LOI (900°C) of 44.467 mass-% in bedrock samples (SD=9.068, n=4) and of 31.423 mass-% in building rock samples (SD=5.892, n=10; (Table 7.3). With a significant linear correlation to the LOI (900°C) (α<0.05), the CaO contents average 44.170 mass-% in bedrock samples (SD=7.169, n=4) and 37.488 mass-% in building rock samples (SD=6.867, n=10). MgO and SiO_2 occur with mean values in the two-digit range (Table 7.3). The mean value of Al_2O_3 is 5.708 mass-% in building rocks (SD=1.333, n=10) and 6.640 mass-% in bedrocks (SD=1.259, n=4). Barium and strontium occur all over in traces. In the marble samples the mean sum of the major oxides and LOI (900°C) totals 104.853 mass-% for the samples originating from building rocks (SD=13.910, n=10) and 116.968 mass-% for bedrock samples (SD=11.423, n=4).

In summary, the comparative analysis shows that the chemical character of samples of the same lithology originating from buildings and source rocks does not differ significantly (α>0.05). Their similarities are also clearly displayed in the matrix plot of ternary diagrams of gneiss oxides (Figure 7.7) and marble oxides (Figure 7.8) (trace elements were not considered in the statistical analysis due to measurement uncertainty). The pattern of the standardized oxides ratio of the ternary diagrams of the granitic gneiss (Figure 7.7) and the marble (Figure 7.8) does not allow clustering to be identified. Data appear in most combinations as undifferentiated point clouds and do not allow a differentiation of provenance based on the chemical characteristics of the rocks.

Table 7.2.: Major and minor element concentration of gneiss rocks (mass-%) (values four times larger than their 1sigma measurement) (1: 900 C, 2: Only oxides)

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	CaO	K_2O	P_2O_5	LOI[1]	SUM[2]	Ba	Zr	Sr	Rb	Zn	Co	V
Granitic gneiss: Building rocks																
AB.32.Bu.	73.010	0.200	11.010	1.410	0.960	5.100	0.110	0.320	91.120	0.150	0.040	0.040	0.010	0.020	0.010	0.010
AB.34.Bu.	72.865	0.192	10.819	1.373	0.948	5.119	0.103	0.297	91.717	0.151	0.002	0.037	0.009	0.009	0.010	0.013
AB.39.Bu.	81.474	0.067	9.386	1.339	0.386	4.910	0.096	0.131	97.788	0.039	0.022	0.002	0.023	0.018	0.022	0.001
BK.09.Bu.	76.224	0.130	11.312	1.546	1.088	5.294	0.117	0.346	96.058	0.061	0.016	0.010	0.018	0.014	0.019	0.005
C.01.Bu.	75.662	0.143	11.208	1.591	1.199	5.113	0.103	0.266	95.286	0.069	0.011	0.011	0.019	0.015	0.017	0.005
J.02.Bu.	77.641	0.138	12.287	1.618	1.187	5.029	0.149	0.296	98.346	0.064	0.012	0.011	0.016	0.016	0.017	0.005
J.03.Bu.	72.209	0.374	11.578	0.933	0.884	5.099	0.153	0.582	91.812	0.217	0.019	0.135	0.010	0.010	0.014	0.020
MR.01.Bu.	77.177	0.098	10.013	1.850	0.724	5.425	0.108	0.323	95.719	0.046	0.021	<d.l.	0.027	0.015	0.010	0.003
MR.04.Bu.	71.380	0.487	11.839	5.763	3.573	0.919	0.208	0.650	94.820	0.057	0.019	0.030	0.001	0.009	0.015	0.005
MR.05.Bu.	73.972	0.377	9.813	1.412	1.235	3.601	0.085	0.375	90.870	0.325	0.006	0.044	0.005	0.012	0.019	0.033
VI.03.Bu.	73.353	0.289	11.664	3.112	1.385	5.345	0.092	0.317	95.554	0.072	0.038	0.009	0.013	0.016	0.011	0.006
VI.04.Bu.	73.107	0.107	12.070	0.848	1.270	4.918	0.082	0.303	92.706	0.123	0.003	0.040	0.008	0.007	0.007	0.009
WM.03.Bu.	74.594	0.142	10.922	1.811	0.752	5.708	0.055	0.503	94.488	0.070	0.016	0.008	0.020	0.012	0.010	0.005
WM.04.Bu.	73.855	0.207	10.378	1.817	1.340	5.280	0.066	0.445	93.388	0.099	0.019	0.019	0.013	0.010	0.014	0.009
WM.07.Bu.	76.080	0.300	10.390	1.830	1.310	5.270	0.150	0.490	94.820	0.060	0.020	0.020	0.010	0.010	0.010	0.010
WM.08.Bu.	74.081	0.337	11.036	2.280	1.291	5.537	0.133	0.440	95.136	0.087	0.027	0.020	0.017	0.013	0.023	0.008
WM.09.Bu.	74.900	0.195	11.647	1.697	1.248	5.714	0.151	0.474	96.025	0.070	0.015	0.015	0.021	0.009	0.009	0.006
WM.16.Bu.	76.179	0.227	11.637	1.831	1.249	5.436	0.149	0.405	97.114	0.059	0.015	0.016	0.025	0.009	0.010	0.006
WM.17.Bu.	77.220	0.274	11.892	2.155	1.364	5.583	0.133	0.531	99.151	0.061	0.020	0.017	0.017	0.012	0.016	0.007
WM.18.Bu.	63.861	0.297	11.308	2.522	1.596	5.361	0.105	0.297	85.347	0.092	0.036	0.010	0.014	0.007	<d.l.	0.006
WM.19.Bu.	76.323	0.197	11.454	1.455	0.961	5.882	0.105	0.367	96.743	0.070	0.018	0.025	0.012	0.011	0.016	0.005
WM.24.Bu.	72.397	0.307	11.348	3.499	1.538	5.008	0.162	0.837	95.098	0.088	0.034	0.021	0.010	0.016	<d.l.	0.006
WM.25.Bu.	74.658	0.158	10.836	1.591	1.112	5.130	0.144	0.465	94.094	0.076	0.012	0.009	0.019	0.023	0.011	0.006
WM.26.Bu.	72.686	0.275	11.206	2.880	1.373	5.558	0.096	0.415	94.489	0.075	0.032	0.011	0.012	0.017	0.013	0.006
WM.29.Bu.	73.128	0.195	10.374	2.066	1.583	4.481	0.135	0.689	92.651	0.079	0.023	0.016	0.012	0.013	0.017	0.006

WM.33.Bu.	69.641	0.198	10.170	0.572	0.523	3.860	0.069	0.344	85.378	0.159	0.004	0.132	0.006	0.010	0.011	0.014
WM.34.Bu.	76.951	0.222	10.788	0.446	0.948	5.899	0.121	0.533	95.909	0.194	0.008	0.037	0.014	0.011	0.017	0.018
Average	74.246	0.227	11.051	1.898	1.223	5.022	0.118	0.424	94.134	0.100	0.019	0.027	0.014	0.013	0.013	0.009
SD	3.168	0.098	0.717	1.041	0.558	0.974	0.034	0.149	3.288	0.063	0.010	0.033	0.006	0.004	0.006	0.006
Granitic gneiss: Source rocks																
AB.03.Be.	73.038	0.304	12.941	3.393	1.329	5.967	0.167	0.812	97.952	0.075	0.025	0.012	0.016	0.015	0.006	0.007
AB.08.Be.	73.365	0.232	11.705	1.914	1.056	5.649	0.160	0.170	94.252	0.085	0.029	0.009	0.014	0.012	0.005	0.007
AB.15.Be.	76.021	0.210	11.539	2.120	1.355	4.906	0.119	0.404	96.675	0.061	0.022	0.004	0.015	0.011	0.014	0.004
AB.20.Be.	71.105	0.259	10.983	2.691	1.393	5.222	0.110	0.367	92.129	0.065	0.030	0.008	0.013	0.016	0.009	0.006
AB.21.Be.	76.252	0.197	11.862	2.541	1.108	5.677	0.140	0.325	98.101	0.076	0.036	0.005	0.013	0.016	0.014	0.007
AB.22.Be.	71.500	0.193	10.093	2.545	0.828	6.054	0.130	0.773	92.116	0.057	0.023	0.003	0.023	0.010	0.014	0.004
BK.03.Be.	72.756	0.219	11.248	2.358	1.229	5.573	0.165	0.499	94.047	0.067	0.026	0.008	0.017	0.015	0.010	0.006
BK.05.Be.	70.726	0.183	12.537	1.748	3.338	1.108	0.156	0.744	90.541	0.052	0.014	0.051	0.002	0.010	0.008	0.004
I.08.Be.	74.143	0.244	10.856	2.605	1.137	5.452	0.078	0.383	94.898	0.081	0.030	0.003	0.023	0.012	0.007	0.006
I.13.Be.	73.376	0.178	11.367	2.157	1.152	5.255	0.098	0.394	93.979	0.069	0.022	0.007	0.017	0.012	0.007	0.005
MR.03.Be	74.786	0.090	10.467	0.971	1.067	4.187	0.069	0.394	92.032	0.106	0.004	0.022	0.005	0.014	0.023	0.009
V.10.Be.	78.964	0.158	10.166	1.446	0.719	5.408	0.082	0.346	97.291	0.050	0.017	0.002	0.020	0.012	0.019	0.004
V.16.Be.	74.915	0.180	11.155	2.611	0.824	5.490	0.108	1.632	96.914	0.057	0.024	0.003	0.022	0.009	0.008	0.004
V.19.Be.	76.402	0.229	11.240	2.175	0.796	5.604	0.142	0.554	97.140	0.054	0.024	0.003	0.025	0.013	0.015	0.005
V.25.Be	76.509	0.209	11.276	2.343	0.775	5.728	0.124	0.642	97.604	0.085	0.022	0.004	0.024	0.013	0.010	0.006
WM.13.Be	70.190	0.075	11.573	0.682	2.943	1.530	0.078	1.278	88.349	0.075	<d.l.	0.065	0.003	0.007	0.007	0.004
WM.27.Be.	73.944	0.178	11.153	1.688	1.285	5.142	0.144	0.580	94.116	0.064	0.014	0.015	0.020	0.009	0.012	0.005
WM.30.Be.	74.842	0.160	10.456	1.462	1.103	5.422	0.112	0.519	94.076	0.056	0.013	0.014	0.023	0.011	0.020	0.004
Average	74.046	0.194	11.256	2.081	1.302	4.965	0.121	0.601	94.567	0.069	0.021	0.013	0.016	0.012	0.012	0.005
SD	2.315	0.054	0.740	0.664	0.704	1.391	0.032	0.359	2.783	0.015	0.009	0.017	0.007	0.003	0.005	0.001
Migmatitic hornblende gneiss: Building Rock																
C.02.Bu.	49.244	1.253	16.433	10.541	6.773	2.575	0.455	0.321	87.595	0.075	0.018	0.043	0.012	0.015	<d.l.	0.013
Migmatitic hornblende gneiss: Source Rock																
WM.23.Be.	46.524	2.704	16.081	14.003	7.789	1.899	0.977	0.275	90.251	0.119	0.01	0.051	0.003	0.016	<d.l.	0.015

Table 7.3.: Major and minor element concentration of marble rocks (mass-%) (values four times larger than their 1sigma measurement)(1: 900 °C, 2: Only oxides)

Code	CaO	MgO	SiO_2	Fe_2O_3	K_2O	P_2O_5	Al_2O_3	LOI[1]	SUM[2]	Ba	Sr
Building Rocks											
AB.33.Bu.	35.564	13.502	9.077	0.519	0.243	0.524	5.142	18.930	83.502	0.050	0.010
AB.35.Bu.	34.369	14.434	11.861	0.501	0.066	0.462	4.970	33.712	100.376	0.040	0.010
AB.36.Bu.	32.456	14.564	10.077	0.591	0.152	0.556	4.809	33.384	96.588	0.045	0.011
AB.37.Bu.	31.969	15.171	9.111	0.567	<d.l.	1.490	4.940	34.285	97.532	0.041	0.001
AB.38.Bu.	31.120	15.250	8.970	0.550	0.150	1.300	4.800	33.290	95.430	0.094	0.023
J.01.Bu.	36.123	13.401	48.293	0.612	<d.l.	0.636	5.151	24.707	128.923	0.043	0.006
V.01.Be	48.100	16.900	8.300	0.300	0.160	0.850	6.910	29.975	111.495	0.039	0.003
V.08.Bu	48.221	16.065	8.479	0.293	0.152	0.693	7.227	37.938	119.068	0.039	0.002
VI.01.Bu.	32.034	17.290	12.769	0.276	<d.l.	0.531	4.648	29.971	97.518	0.039	0.003
VI.02.Bu.	44.922	16.353	8.254	0.605	0.780	0.654	8.484	38.042	118.094	0.040	<d.l.
Average	37.488	15.293	13.519	0.481	0.243	0.770	5.708	31.423	104.853	0.047	0.007
SD	6.867	1.348	12.313	0.137	0.242	0.350	1.333	5.892	13.910	0.017	0.007
Bedrocks											
KN.01.Be.	49.408	15.919	9.780	0.226	<d.l.	0.753	7.389	32.494	115.969	0.047	0.030
MG.04.Be.	42.940	17.527	6.801	0.240	<d.l.	0.618	6.779	54.460	129.365	0.039	0.006
MG.06.Be.	49.820	17.531	0.160	0.167	<d.l.	0.698	7.571	44.593	120.539	0.043	0.044
MG.11.Be.	34.510	15.604	<d.l.	0.299	<d.l.	0.446	4.820	46.320	102.000	0.040	0.011
Average	44.170	16.645	5.580	0.233	<d.l.	0.629	6.640	44.467	116.968	0.042	0.023
SD	7.169	1.029	4.925	0.054	<d.l.	0.134	1.259	9.068	11.423	0.004	0.018

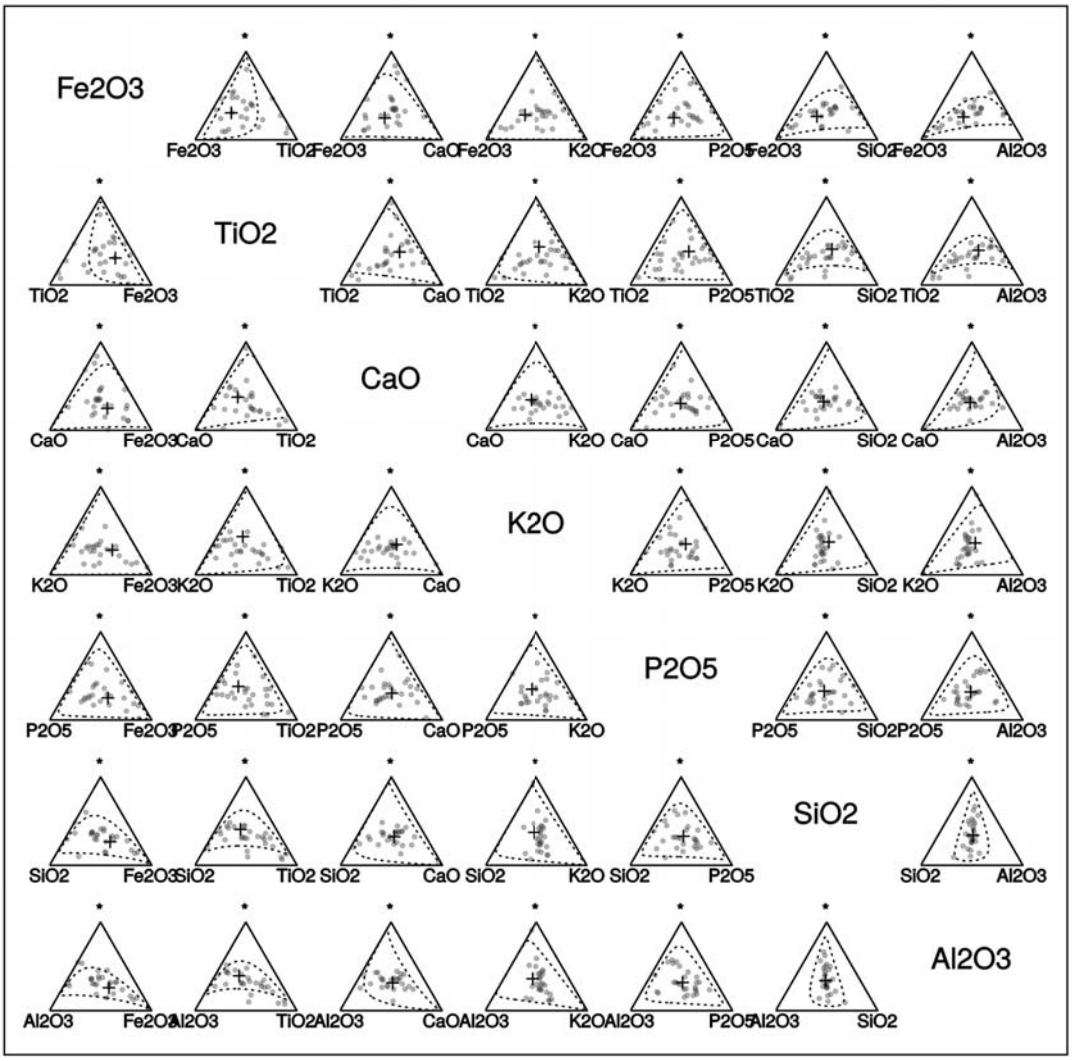

Figure 7.7.: Matrix plot of ternary diagrams of oxides in gneiss rocks (n=47). The matrix plot does not show dissimilar characteristics. The third component equals the geometric mean of the remaining components. Cross (+) shows the mean of the characteristics of the source rock samples, dashed ellipse shows 95% confidence region of the source rocks; grey dots indicate the characteristics of the different building rock samples; (a) raw compositional values; (b) shows the same pattern where the values are scaled and centered to gain a better visual impression.

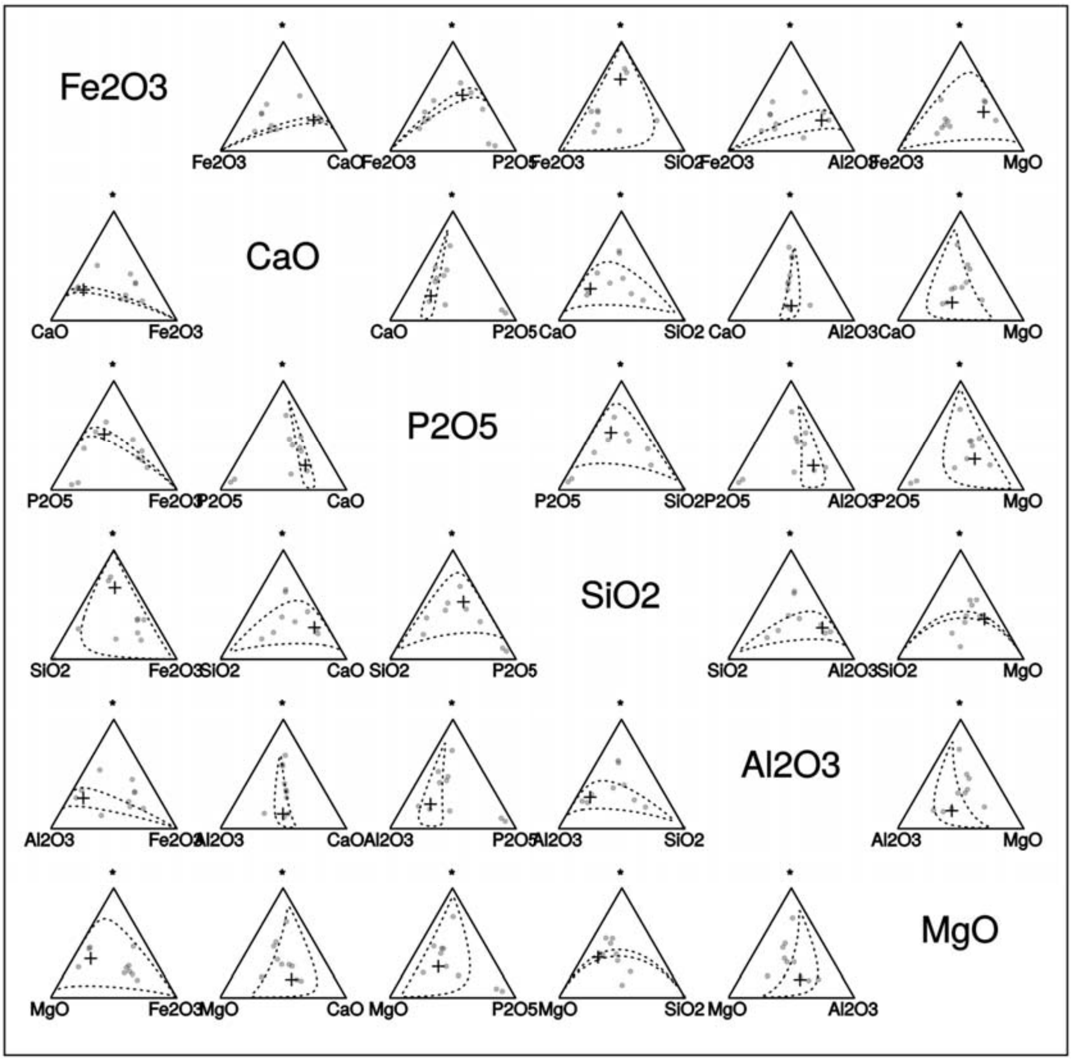

Figure 7.8.: Matrix plot of ternary diagrams of oxides in marble rocks (n=14). The matrix plot does not show dissimilar characteristics. The third component equals the geometric mean of the remaining components. Cross (+) shows the mean of the characteristics of the source rock samples, dashed ellipse shows 95% confidence region of the source rocks; grey dots indicate the characteristics of the different building rock samples; (a) the raw compositional values; (b) the same pattern where the values are scaled and centered to gain a better visual impression.

7.5.4. Chemical characteristics of the rocks

XRD analyses reveal that the granitic gneiss consists mainly of quartz with minor constituents of feldspar such as orthoclase, microcline, plagioclase and anorthite (Table 7.4). Hornblende, biotite and muscovite are other minor constituents encountered in some samples. Accessory minerals such as dispoide and enststite are occasionally found. These observations apply to all building rock and bedrock samples. Migmatitic hornblende gneiss (C.02.Bu and WM.23.Be) is characterized by feldspar as the major mineral with minor quartz (Table 7.4).

Table 7.4.: Mineral composition of gneiss rock samples. (+++ major components, ++ minor components; max. contents per sample are highlighted in gray). Dol=dolomite, Cal=calcite, An=anorthite, Qz=quartz, Ma=muscovite, Bt=biotite (Whitney and Evans, 2010)

	Qz	Or	Mc	Pl	An	Hbl	Bt	Ms	Di	En	Car	Pal
Granitic gneiss: Building rocks												
AB.32.Bu.	+++	++	++		++				+	+		
AB.34.Bu.	+++	++	++	++	++					+	+	+
AB.39.Bu.	+++	++	++	++	++				+	+	+	
BK.09.Bu.	+++	++			++			++	++	++	++	
C.01.Bu.	+++	++	++	++	++				+	+		
J.02.Bu.	+++	++	++	++	++				+	+		
J.03.Bu.	+++	++	++	++	++				+	+		
MR.01.Bu.	+++	++	++		++				+		+	
MR.04.Bu.	+++				++				+		+	
MR.05.Bu.	+++	++	++		++					+	+	
VI.03.Bu.	+++	++	++		++				+		+	
VI.04.Bu.	+++	++	++	++	++				+	+		+
WM.03.Bu.	+++	++	++		++					+	+	
WM.04.Bu.	+++	++	++		++				+			
WM.08.Bu.	+++	++	++		++				++	++		
WM.09.Bu.	+++	++	++		++				+		+	
WM.16.Bu.	+++	++	++		++		++		++	++		
WM.17.Bu.	+++	++	++		++				+			
WM.18.Bu.	++	++	+++		++		++		++	++		
WM.19.Bu.	+++	++	++		++					+		
WM.23.Be.	++			++		++	++	++	++	++		
WM.24.Bu.	+++	++	++		++		++		++			
WM.25.Bu.	+++	++	++		++		++		++	++		
WM.26.Bu.	+++	++	++		++				+		+	+
WM.29.Bu.	+++	++	++		++				+	+	+	+
WM.33.Bu.	+++	++		++	++				+	+	+	
WM.34.Bu.	+++	++		++	++				+	+	+	
Granitic gneiss: Source rocks												
AB.03.Be.	+++	++	++		++				+	+		
AB.08.Be.	+++	++	++		++				+	+	+	+
AB.15.Be.	+++	++	++	++	++				+	+		
AB.20.Be.	+++	++	++	++	++	++				++		
AB.21.Be.	+++	++	++	++					+		+	+
AB.22.Be.	+++	++	++		++				+	+		
BK.03.Be.	+++	++			++				+	+	+	
BK.05.Be.	+++				++						+	
I.03.Be.	+++	++			++	++	++		++		++	

I.08.Be.	+++	++	++		++				+	+		
I.13.Be.	+++	++	++	++	++		++			++		
MR.03.Be.	+++	++	++		++					+		
V.10.Be.	+++	++	++		++					+		
V.16.Be.	+++		++		++		++					
V.19.Be.	+++	++	++		++		++			++		
V.25.Be.	+++	++	++		++		++					
WM.27.Be.	+++	++	++		++				+		+	+
WM.30.Be.	+++	++			++			++	++		++	
Migmatitic hornblende gneiss: Building Rock												
C.02.Bu.	++	++		+++	+++	++	++			++		
Migmatitic hornblende gneiss: Source rock												
WM.23.Be.	++			+++		++	++	++	++	++		

Dolomite and calcites are the major rock-forming minerals in all marble samples (Table 7.5). Quartz and silicates are encountered as minor mineralogical components. In general, marble samples originating from buildings have a similar mineralogical composition to those from the two marble exposures investigated.

Table 7.5.: Mineral composition of marble rock samples. (+++ major components, ++ minor components; max. contents per sample are highlighted in gray). Dol=dolomite, Cal=calcite, An=anorthite, Qz=quartz, Ma=muscovite, Bt=biotite (Whitney and Evans, 2010)

	Dol	Cal	An	Qz	Ma	Bt
Building rocks						
AB.33.Bu.	+++	+++			++	
AB.35.Bu.	+++	+++		++	++	++
AB.36.Bu.	+++	+++			++	
AB.37.Bu.	+++	+++				
AB.38.bu.	+++	+++			++	
J.01.Bu.	+++	+++		++		
V.01.Bu.	+++	+++		++		
V.08.Bu.	+++	+++		++		
VI.01.Bu.	+++	+++				
VI.02.Bu.	+++	+++		++		
Bedrocks						
KN.01.Be.		+++				
MG.04.Be.		+++	++			
MG.06.Be.	+++	+++			++	
MG.11.Be.	+++	+++				

7.6. Discussion

7.6.1. Geochemical and mineralogical composition and petrology

The comparison of the rock chemistry of the samples investigated in this study with data from other regions in Sri Lanka (Table 7.6) shows that the chemical composition of the granitic gneiss originating from the surroundings of Anuradhapura is largely similar to that of the granitic gneiss analyzed by Pohl and Emmermann (1991). The Al_2O_3 and Fe_2O_3 contents of the migmatitic gneisses are comparable to one another. Contents of SiO_2 vary up to 10% between the two studies, corresponding to the high variability of free silica occurring in granitic bedrock (Katupotha, 2014, 328). In consequence, the chemical character of the major building rocks does not represent a distinct reference to its provenance. Furthermore, the chemical analysis of the marble samples of building rocks and bedrock also does not allow a distinct provenance assignment.

Table 7.6.: Whole rock chemistry of granitic gneiss, migmatitic gneiss and marble of the study area and its surroundings and other areas of the country. A=Pohl and Emmermann (1991), B=Anuradhapura. C=Pitawala (2003)

	Granitic gneiss		Migmatitic gneiss		Marble	
	A (n=14)	B (n=47)	A (n=14)	B (n=2)	C (n=1)	B (n=14)
SiO_2	71.04	74.17	60.59	47.85	11.29	12.91
TiO_2	0.51	0.21	1.17	1.98	-	-
Al_2O_3	12.09	11.13	17.53	16.25	0.07	5.94
Fe_2O_3	0.09	1.97	10.03	12.25	0.62	0.45
FeO	2.96	-	-	-	-	-
MnO	0.07	-	0.24	-	-	-
MgO	0.53	-	2.95	-	4.11	15.45
CaO	2.14	1.25	1.94	7.28	48.47	38.98
Na_2O	2.42	-	2.35	-	0.06	-
K_2O	5.05	5	3.06	2.24	-	0.14
H_2O+	0.24	-	-	-	-	-
P_2O_5	0.13	0.12	0.06	0.72	0.08	0.73
CO_2	0.28	-	-	-	-	-
LOI	-	0.49	-	0.3	34.5	33.73
Total	97.05	94.31	99.93	88.95	99.2	109.17

XRD analysis shows that building and bedrock samples of gneiss rocks have quartz as the major rock-forming mineral (Table 7.4). The results of the present study are comparable to previous studies by (Ratnayake and Pitawala, 2009, 1029). Orthoclase, icrocline, plagioclase and anorthite are found as minor minerals in the gneiss samples. In contrast to granitic gneiss, migmatitic hornblend gneiss is rich in feldspars. The calcite content of some samples of marble is particulary high, compared to marble found in other areas of the country (Madugalla et al., 2013).

The gneiss rocks belonging to the Wanni Complex of Sri Lanka and originating from the area around Anuradhapura (Cooray, 1994) are characterized by well-developed joints along the foliation plains. Ductile and brittle structures in rocks represent favorable conditions for rock harvesting (Ritchie, 1999; Smith and Bruhn, 1984 bedrock outcrops with bedded layers, natural foliations or mechanical weathering fractures were preferably used for quarrying in ancient cultures (Dworakowska, 1975, 97; Heldal, 2009, 129; Kelany et al., 2009, 89; Schierhold, 2009, 38). Levers were used to widen these natural cracks and joints in the bedrock (Heldal, 2009, 89), a technique frequently used in the surroundings of Anuradhapura (Wagalawatta et al., 2016) (Figure 7.6).

7.6.2. Local versus imported construction material

The spatial juxtaposition of quarrying sites for gneissic building rock exploitation and monumental buildings clearly indicates that ancient architects preferred to use bedrock from local sources as a construction material for non-decorative purposes. This observation can be clearly verified by focusing on the Western monasteries, which are located in the migmatic hornblende gneiss zone and where migmatic hornblende gneiss is the prevailing construction material. The majority of constructions in the ancient center of the city are built of granitic gneiss (Figure 7.1a), which crops out along the central rock outcrop line from where it was systematically mined (Wagalawatta et al., 2015) (Figure 7.1a). This observation emphasizes the attraction of utilizing local bedrock resources as construction materials in order to minimize the effort of transport. In the wider surroundings of Anuradhapura, locations with outcropping bedrocks are scarce. In addition to other natural resources, Chisholm (2007, 114), mentions the availability of rocks as building materials as one locational factor influencing the establishment of settlements. The presented results show that this also holds true for the development of Anuradhapura to become the capital of the Anuradhapura kingdom.

In addition, the ancient citizens of Anuradhapura used marble, a bedrock that generally occurs rarely in the central lowlands of Sri Lanka, for ornamentation and decoration, especially of sacred buildings and monuments. In this case the necessity of long transportation routes was accepted (De Jayawardena, 2015, 45; Jayasinghe, 2013; Katupotha, 2014, 328) (Figure 4b, c). Rea (2000, 15) and Sen (1999, 174) state that the use of marble for the construction of Buddhist sacred monuments and the decoration of sacred constructions was a common practice in ancient India. In the immediate vicinity of Anuradhapura there are no outcrops with (high-quality) marble, consequently marble had to be mined in more distant places. The nearly exclusive use of marble for ornamentation and decoration documents its high sacred value, which renders its quarrying profitable despite the transportation costs.

The import of exotic or outstanding building materials from distant locations for selected architectural features, ornamentation and decoration are also documented for other ancient civilizations such as Ancient Egyptian and Roman cities (Degryse et al., 2008, 269; Klemm and Klemm, 2001, 631). The specific use of individual types of construction rocks for particular construction purposes even in the same building has been known since the Bronze Age (Philokyprou, 2011, 50). For example, Bronze Age settlers transported a particular rock type over a long distance for the construction of monumental buildings in Cyprus (Philokyprou, 2011, 42). Some of the pillars in the Roman theater in Catania/Sicily were constructed with material that was imported from eastern Turkey and the island of Elba, while for the general construction volcanic rocks quarried in the vicinity of the city were used (Corsaro et al., 2000, 254).

Bandaranayake (1974, 25) states that marble became a popular building material in the ancient Sinhalese built environment after the 6th century CE. Chronologically, this increased application of marble for decoration purposes coincides with the time when Anuradhapura became the capital of a state that built its agricultural production on irrigation agriculture and implemented a sophisticated network of tank-cascade systems across the country (Seneviratne, 1994; Dahdouh-Guebas et al., 2005) (Table 7.1). Archaeological evidence recorded from the excavations in the Citadel of Anuradhapura illustrate that the city simultaneously extended its power to exploit natural resources from far distant locations, e.g. iron from Seruvila (on the east coast of Sri Lanka) (Seneviratne, 1995). The city had further foreign trade relations reaching into the Mediterranean region (Coningham, 2006; Coningham, 1999; Deraniyagala, 2004a) (Table 7.1). The Chinese Buddhist monk Fa-Hsiaen, who visited Anuradhapura in the 5th century CE, reported that the city of Anuradhapura was a Buddhist centre with around 60,000 monks then living in monasteries in and around the city (Fa Hsien, 1923, xxxviii). According to Gringmuth-Dallmer (2011) and Knitter et al. (2013), this kind of archaeological evidence is a marker for a central place with centralized religious, cultural and political power. Thus it can be assumed that in Anuradhapura the utilization of marble, as a special and valuable building material, emerged with the subsequent development of the capital as a place of centralized political and religious power.

7.6.3. Morphological privileges of outcropping rocks

Since the beginning of Buddhist civilization, monks had a tradition to use rock shelters as habitation places (Figure 7.9a) (Coningham, 1995; Mahavamsa, 1912, 112; Rahula, 1956). Rahula (1956, 114) described that in ancient times rock shelters were cleaned using fire. The Early Brahmi inscriptions written underneath the drip ledges document that these rock shelters were used arround 300 BCE as basal early settlements (Coningham, 1995, 229; Paranavithana, 1970, lxvii) (Table 7.1). Moreover, Mesolithic stone tools from the cave shelters in the Vessagiriya monastery illustrate that they were used as habitation places even much earlier(Mendis, 2014, 6).

Buddhist settlers also favored to build their sacred buildings on elevated surfaces, considering the height has a sacred value and using its protective function (Wijesuriya, 1998, 15). Some boulders throughout the rock outcrop line in Anuradhapura clearly illustrate that ancient settlers used the top elevations of the outcropping boulders as platforms to build sacred shrines (Wagalawatta et al., 2015). The establishment of sacred shrines on high elevations similarly occurs also in the Mihinthale monastery (Cave, 1907, 36). In comparison with the Asian context, the establishment strategy of the Buddhist temple Kyaiktiyo, Myanmar also shows a similar arrangement (Reid and Grosberg, 2005, 33). Moreover, numerous boulder tops on which monuments were and rock shelters in the settlement illustrate that those locations were the former quarry locations, where building materials for the constructions were supplied (Wagalawatta et al., 2015) (Figure 7.9c).

Sri Lanka has a long tradition of water management based on reservoirs (Dahdouh-Guebas et al., 2005, 579), representing a sustainable watershed management strategy for more than 2000 years (Schütt et al., 2013, 66). These tanks store the water for agricultural use (Jayatilaka et al., 2003) as well as for domestic aims (Mahatantila et al., 2008, 17; Vidanage et al., 2005, 16). In the immediate vicinity of the city of Anuradhapura also numerous reservoirs occur, dammed in the shallow valleys west of the rock outcrop line (Figure 2a). Mendis (2014, 7) mentiones that due to the low relief the slow surface runoff in the valleys caused the development of extended wetland areas in the alluvial plains. Since Lower Early Historic period 500-250 BCE demographic expansion caused increased water demand, complied by the construction of dams across the thalweg, favoured wherever the rock outcrop line was cut off (Mendis, 2014, 12) (Figure 7.9b).

Figure 7.9.: Morphological privileges of outcropping rocks in the cultural landscape of Anuradhapura. (a) A utilized natural rock shelter as a living place, which is located in the Vessagiriya monastery (red line shows the embossed drip ledge over the roof portal). (b) View (east to west) of the (2) soil bunt of Tisawewa adjacent to the (1) rock outcrop line in the Ranmau Uyana (The water garden), (c) The resorted ancient stupa located on the rock boulder in the Isurumuniya monastery. (Photographs by Wagalawatta 2014)

7.7. Conclusions

This investigation analyzes the influence of local stone resources on the establishment and development of the ancient city of Anuradhapura. The availability of outcrops along the N-S rock outcrop line provided suitable construction rocks for the erection of monuments and was probably a strong locational factor in the selection of stable settlement sites. This is clearly documented by the close spatial relation between monuments and the quarrying sites where the construction rocks originate from.

The majority of the building stones that were used in ancient constructions during the early phases of Anuradhapura are granitic and migmatitic gneiss; they dominate the ordinary constructions reflecting their availability within the settlement area. With the subsequent development of the administrative, religious and social functions of the city, increasingly prestigious constructions were erected. The analysis clearly demonstrates that regionally scarce rocks such as marble were brought from distant quarrying sites for decoration and ornamentation purposes.

The designation of Anuradhapura as the capital of the ancient kingdom of Anuradhapura, situated in the midst of the north-central lowlands, required that it possess additional attributes in addition to the availability of construction material. The area is characterized by a semi-humid tropical climate, marked by two annual rainy seasons. The landscape of the north-central lowlands is flat, characterized by slopes inclining 1-3° and a dense drainage network with only slightly incised channels. These characteristics were ideal preconditions for the extensive landscape engineering measures that the settlers of the Anuradhapura kingdom initiated: the establishment of a sophisticated tank-cascade system which allowed year-round water storage and thus the irrigation and cropping of rice as a staple food (Schütt et al., 2013). The shallow relief allowed the adoption and construction of water storage systems without sophisticated technological knowledge, as flow velocities were relatively low.

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7.8. Supplementary material

From the sample set twelve samples were selected to establish an internal set of reference materials. Eight powdered samples with CaO contents <32% and four samples with CaO contents >32% were sent to the Institute of Applied Geosciences at the Technische Universität Berlin for WD-XRF measurements. From these twelve samples fused beads were prepared with 0.6g of unannealed sample powder (<50µm) and 3.6g of "FLUXANA" borate mixture that were fused in Pt/Au-crucibles in a "Rotomelt" induction furnace at 1000°C for 6 minutes. The liquefied sample was poured into a 26mm Pt/Au-coquille and cooled to a vitric matrix. The fused beads were measured with a PHILIPS ED-XRF PW 2400. The loss on ignition at 1000°C was determined by thermogravimetry for all twelve samples.

Two different suites of WD-XRF measurements against varying CRMs were performed for samples with CaO values >32% and CaO values <32%. The sum of all elements and the LOI came to 97.9 to 99.8% for the sample with <32% CaO contents. For the samples >32% CaO the sum of elements and the LOI came to 100.2 to 101.0%. The resulting values are regarded as the "most-precise" values and provided the base for the set of internal reference material.

As the remaining samples were to be measured with a p-ED-XRF-spectrometer, pellets were also prepared from the powdered samples of the internal reference material (IRM) that had previously been measured with the WD-XRF-spectrometer. These pellets were used to produce an IRM-set with the p-ED-XRF analyses in comparison to the base of the WD-XRF results. Recovery rates were calculated in percentages for the p-ED-XRF measurements of the IRM by using the results of the WD-XRF measurements as the index value (Table 7.7. From these results it was decided to use the following ten elements for further interpretation: Al, Ba,Ca, Fe, K, P, Rb, Si, Sr, Ti.

Table 7.7.: p-ED-XRF Specifications

X-Ray Source	Ag-anode
Umax • Imax	2W
Umax	40kv
Imax	100 ćA
Used Filters	
Main	Main 30 sec at 50 kV with 40 ćA
Low	30 sec at 20 kV with 100 ćA
Light	30 sec at 8 kV with 250 ćA

CHAPTER 8

Conclusions

The ancient city of Anuradhapura is located in north-central Sri Lanka and was the capital of the Sri Lankan kingdom between the 4^{th} century BCE and the 11^{th} century CE. The availability of natural resources played a pivotal role in sustaining the foundation and successive development of ancient settlements. Numerous architectural remains in the ancient city of Anuradhapura document vivid construction activities and point to the significance of bedrock availability as a resource allowing the sustainable construction of architectural buildings. To gain a better understanding of the spatial and temporal relation between rock-mining and rock-consumption areas of the ancient Anuradhapura city, ancient rock quarries and landscape dynamics related to the quarrying of bedrock are analyzed. The assessment of the availability of rocks for construction purposes as a selection criterion for the settlement site has to be related to other locational factors allowing for the implementation of landscape engineering to improve resource availability.

Quarry sites in the hinterland of Anuradhapura can be classified according to their morphological features and subsequent usage into (i) boulder quarries, (ii) boulder-top terrace quarries, (iii) rock-shelter quarries, (iv) surface quarries, (v) pit quarries and (vi) tank-bottom quarries (Figure 8.11a, I,II,III,V). Quarries are predominantly located along the rock outcrop line. The majority of construction material in the ancient city center corresponds to granitic gneisses. Marble, a material important for decoration and ornamentation had to be imported from remote locations such as the village Kanadarawa (15 km northeast of Anuradhapura city) and the village of Medagama (31 km south of the ancient city). However, further investigations are recommended to confirm whether these two locations were the only marble exposures close to the ancient city.

The comparison of chemical, mineralogical, and petrographic data of rocks used in the ancient constructions and source rocks do not allow a clear provenance analysis. Since the quarry sites of granitic and migmatitic hornblende gneiss are located within the settlement, it is concluded that ancient settlers quarried gneissic materials from the local sources for on-site constructions (Figure 8.11a). In contrast, imported marble rocks were utilized for the constructions of sacred Buddhists monuments from the 6th century CE onwards (Figure 8.11b). The utilization of marble in representative buildings seems to have emerged with the subsequent development of the settlement as a capital with corresponding religious, economic and social values. Systematic archeological excavations following subsequent stratigraphic phases of building constructions will be necessary to get a precise idea of the dating of stone constructions in Anuradhapura.

In the ancient quarries chiseled quarry holes were regularly observed, indicating the prominent rock quarrying technique common among ancient stoneworkers in Anuradhapura. Based on an ethnoarcharchaeological approach, a traditional working craftsman was observed in order to gain information about ancient rock quarrying techniques. From observations of his work flow when splitting the rocks two major work steps were identified: (i) a series of oval shaped holes are chiseled following the border of the block to be separated and (ii) a fracture line is created through the holes to separate the intended blocks from parent rocks. Cylinder-shaped iron chisels and hammers were used as tools to bore the quarry holes, and flat wedges, iron feathers, and a hammer were applied to produce pressure from the holes in the rock.

At several sites in the hinterland of Anuradhapura it can be observed that after the exploitation of building materials the sites were integrated into the landscape as basins to store water (Figure 8.11b, XI), enlarged rock shelters as living spaces (Figure 8.11b, IX) and as platforms to build Buddhist religious buildings on (Figure 8.11b,X). Moreover, the availability of outcrops along the N-S-striking rock outcrop line in the local topography was a strong locational factor influencing the selection of the stable settlement sites and the positioning of ancient tanks (Figure 8.11b, VIII).

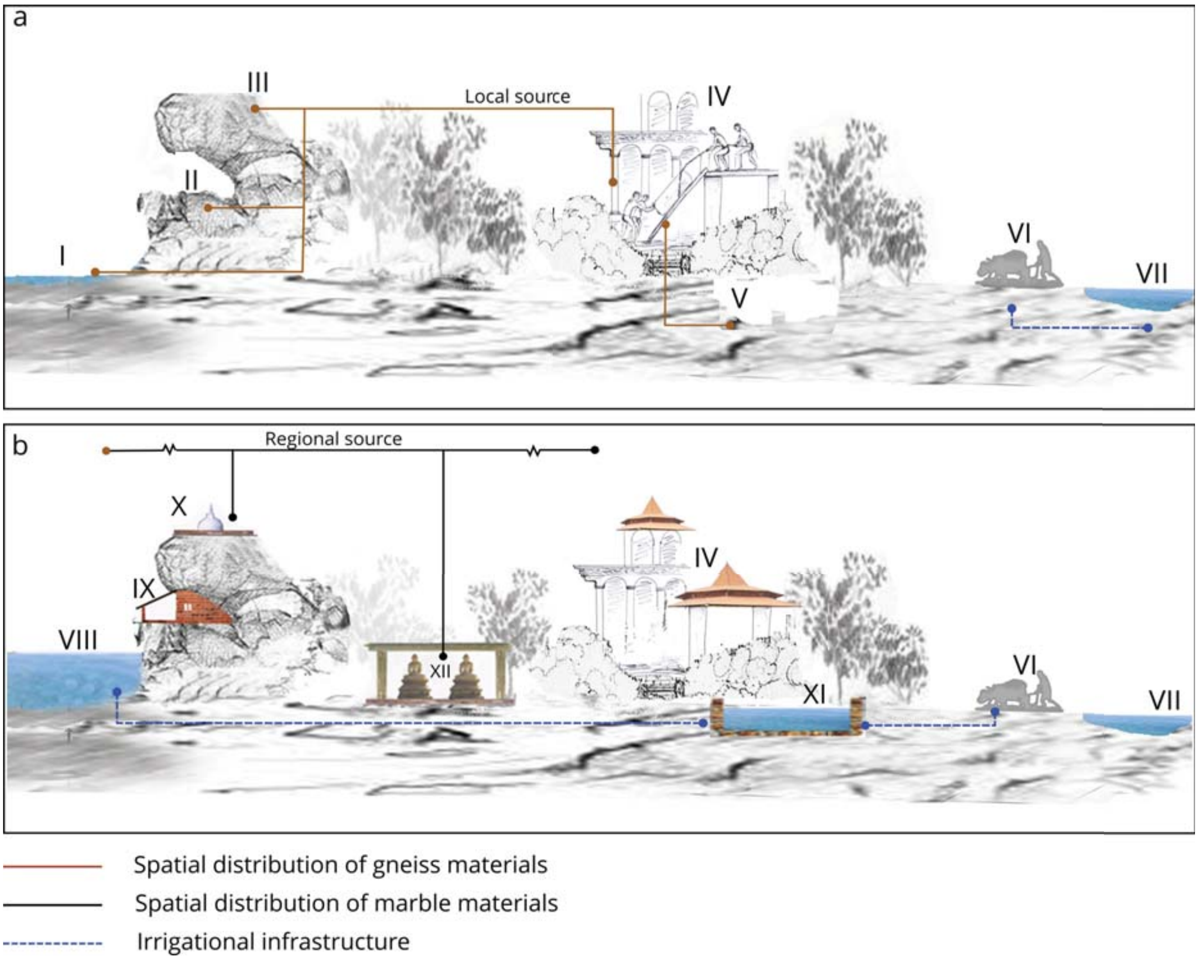

Figure 8.1.: Manipulation of stone resources in the cultural landscape of ancient Anuradhapura. (a) Preliminary phase: The erection of the ordinary constructions of the settlements based on the local materials. Ancient quarrymen focused on mining building materials, (I) on the bottoms of the tanks, (II) inside the rock shelters, (III) top level of the boulders and (V) digging pits. (VI) Agricultural hinterlands and (VII) the River Malwatho Oya. (B) Developed phase: (VIII) The manmade tanks (reservoirs) located on the west side of the rock outcrop line thus allowing ancient settlers to enable easy water supply to the main settlement located between the rock outcrop line and the River Malwathu Oya, with the support of gently declining relief. (IX) Converted rock shelters as living spaces, after exploitation of a certain amount of building materials, similarly (X) boulder tops were used to establish sacred monuments. (XI) Converted pit quarries as basins for storage water. During the developed settlement phase, ancient settlers used marble materials for the construction of sacred Buddhist monuments such as (X) sthpa, (XII) Buddha statues.

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APPENDIX A

Appendix

A.1. Synopsis of the cultural sequence and material evidenced steamed out from the excavations on the Citadel of Anuradhapura

Appendix A1: Synopsis of the cultural sequence and material evidenced steamed out from the excavations on the Citadel of Anuradhapura

Periods and their dates according to Deraniyagala	**Period I: Meso-lithic**	**Period II: Meso-lithic Iron age transi-tion**	**Period III: Protohistoric Iron Age (Early Iron Age)** ca. 900 – 600 BCE	**Period IV: Basal Early Historic (Transition between Early Iron and Lower Early Historic)** ca. 600 – 500 BCE	**Period V: Lower Early Historic** ca. 500 – 250 BCE	**Period VI: Mid-Early Historic** ca. 250 BCE – 100 CE	**Period VII: Upper Early Historic** ca. 100 – 300 CE	**Period VIII: Middle Historic** ca. 300 – 1250 CE
Index fossils according to Deraniyagala	Geo-metric microliths		Appearance of iron technology, and of pottery (Sri Lankan variant of BRW)	Appearance of signs (Brahmi script), and of rim type AG-69:8, and an ‘archaic’ variant of AG-69:22b(i) bowl of low-lustre, medium-fine paste, medium-light grey ware	Profusion of rim type AG-69:8, supersession of roof-tile type AG-69:35b(i) by type:35a(ii)	Appearance of RLW, Brahmi script on pottery, seals and stone, coinage (punch-marked and ‘elephants and swastika’ types), lakshmi plaques, glass, gradual rise to prominence of burnt bricks as building material	Appearance of RPW, numerous coins (‘tree and swastika’, Indo-Roman and Roman); pale blue ‘Sassanian’ glazed ware coeval with glazed roof-tiles type AG-69:35a(i); BRW in use up to end of period VII	Profusion of West Asian ceramics with appearance in 8th and 9th centuries, supplemented by Chinese wares from 9th to 11th centuries supersession of brick by ashlar
Citadel 1969 + AG-85 (Deraniyagala 1972:150,155,159,160) + (Deraniyagala 2004:715, 718)	*Stratum 1:* Meso-lithic geometric microliths Balan-goda Culture Stratum 1 Beta-18435: 5040±80 BP BM-2510: 5040±50 BP		*Stratum 2 (with probable inclusions from overlying protohistoric contexts):* Metal-working slag, horse. *Stratum 3a:* Occurrence of stone sculpture Stratum 2 Beta-15336: 2390±60BP Stratum 3a Beta-15341: 2220±80 BP Beta-15340: 2370±60 BP Beta-15339: 2340±60 BP BM-2508: 2520±50 BP Beta-15338: 2410±60 BP BM-2509: 2470±50 BP	*Stratum 3a/3b transition:* First appearance of rim type 8 and roof type 35a overlapping with final occurrence of roof-tile type 35b Stratum 3a/3b transition Beta-15348: 2440±70 BP	*Stratum 3b (mixture of artefacts of 3a and 4):* NBPW, roof-tile type 35a, rim type 8. Stratum 3b BM-2506: 2170±50 BP Beta-18436: 2270±100 BP Beta-15342: 2360±70 BP	*Stratum 4a:* RLW, Lakshmi plaque Stratum 4b: RLW, seal with Brahmi inscribed. Stratum 4a Beta-15345: 2290±90 BP Beta-18437: 2140±60 BP BM-2505: 2130±50 BP Stratum 4b Beta-18438: 2060±80 BP Beta-15347: 2110±70 BP Beta-15346: 2050±70 BP		
AGP 87 (Deraniyagala 2004:719)								*Context AGP 87* Ashlar shrine with carved guard stone. Context AGP 87 Beta-19624: 1630±70 BP

ADB 87/ 88 (Deraniyagala 2004:719)		*Context 91, 99* Lowermost context of protohistoric Iron Age Context 91 Beta-36617: 2470±50 BP Context 99 Beta-36614: 2420±60 BP		*Context 65* Rim type 8 Context 65 Beta-36616: 2240±70 BP	*Context 54* RLW, NBPW *Context 57* RLW Context 54 Beta-36612: 2150±60 BP Context 57 Beta-36613: 2080±70 BP
AMP 88 (Deraniyagala 2004:721)	*Context 79* (Lowermost horizon) *Context 85* (top soil and basal horizon) Context 79 Beta-35716: 2530±110 BP Context 85 Beta-35717: 2690±90 BP	.	*Context 54* Rim type 8 *Context 67* actual date falling outside the radiocarbon range *Context 72* *Context 75* (lowermost horizon) Potsherds inscribed with an early Brahmi characters Context 54 Beta-35712: 2320±60 BP. Context 67 Beta-35713: 2660±100 BP. Context 72 Beta-35714: 2320±90 BP. TL Dating 376-216 BC (random) TL Dating 456-136 BC (Systamatic and random) Context 75 (Lowermost horizon). Beta-34392: 2350±110 BP Beta-35715:2560±70 BP CCF-A3: TL Dating on pottery 563-390 BC (random) TL Dating 649-305 BC (Systematic and random). CCF-B1: TL Dating on pottery 547-382 BC (random) TL Dating 641-297 BC (Systematic and random). CCF-B2: TL Dating on pottery 572-399 BC (random) TL Dating 645-301 BC (Systematic and random). CCF-C2: TL Dating on pottery 562-390 BC (random) TL Dating 648-223 BC (Systematic and random).	*Context 44* Rim type 8, heavy strong vessels of buff ware with? resin residue Context 44 Beta- 35710: 2090±70 BP Context 49 Beta-35711: 2060±60 BP	

ASW 88/88 (Deraniyagala 2004:724)			*Context 89* Medium-fine gray ware *Context 96* Lowermost protohistoric Iron Age habitation *Context 97* Top soil with protohistoric Iron Age artefacts Context 89 Beta-33278: 2560±100 BP Context 96 Beta-33279: 2690±60 BP Context 97 Beta-32280: 2640±60 BP		*Context 78* Lover Early historic and Mid Early Historic transition. RLW pottery *Context 79* RLW pottery *Context 88* Type 8 (Basal Horizon) Potsherds with early Brahmi Context 78 Beta-36624: 2250±60 BP Context 79 Beta-33276: 2430±70 BP Context 88 Beta-33277: 2520±70 BP	*Context 58* Late occurrence of RLW pottery, Lankshimi coins, Tree and swastika coins, Cupper coin and a square of elephant and fish, Pandyan coin *Context 62* Lankshimi coins, Romans coins, tree and swastika coins, elephantand swastika coins *Context 64* RLW pottery, lack of Roman coins. Context 58 Beta-33275: 2080±70 BP Context 62 Beta-36622: 2100±70 BP Context 64 Beta-36623: 2110±70 BP	*Context 49* Sassanian glazed ware. Lankshimi coins, Tree and swastika coins, BRW pottery, Roman coins Context 49 Beta-36621: 1850±60 BP	
ASM 89 (Deraniyagala 2004:728)			*Context 76* One of the basal habitation deposits of the protohistoric Ion Age. Slag from metal working. Context 76 Beta-36620: 2610±80 BP					
Periods and their dates according to Deraniyagala	**Period I: Meso-lithic**	**Period II: Meso-lithic Iron age transi-tion**	**Period III: Protohistoric Iron Age (Early Iron Age)** ca. 900 – 600 BCE	**Period IV: Basal Early Historic (Transition between Early Iron and Lower Early Historic)** ca. 600 – 500 BCE	**Period V: Lower Early Historic** ca. 500 – 250 BCE	**Period VI: Mid-Early Historic** ca. 250 BCE – 100 CE	**Period VII: Upper Early Historic** ca. 100 – 300 CE	**Period VIII: Middle Historic** ca. 300 – 1250 CE
ASW 2: Structural Periods and their dates according to Coningham 1999 125-131,209			*Structural period K* ca. 840 – 460 BCE	*Structural period J* ca. 510 – 340 BCE	*Structural period I* ca. 360 – 190 BCE	*Structural period H and structural period G* ca. 200 BCE – 130 CE		*Structural period F* ca. 200 – 600 CE *and Structural periods E,D,C and B* ca. 600 – 1100 CE

	Structural period K	*Structural period J*	*Structural period I*	*Structural period H*	*Structural period F*
ASW 2 (Coningham 1999, 2006:5)	*K1 – 3:* Lightly constructed, perhaps temporary structures (postholes), BRW pottery, iron objects and iron-working technology; cattle, hare and deer remains. Sherds bearing non-scriptural graffiti and 'megalithic symbols' K1 (context 1811) Beta-48916: 2550±80 BP K2 (context 1714) Beta-48917: 2360±70 BP K3 (context 1616) Beta-48920: 2490±60 BP	*J1 - 5:* Round timber structures as living places (postholes) , small furnace or an oven, one iron arrow head, copper alloy wire. beads, iron slag, iron, quartz objects, copper, BRW, in J3: first appearance of early Brahmi scriptural graffiti, in J4: early Brahmi inscription J1 (context 1496) Beta 48921: 2310±100 BP J2:(context 1417) Beta 48922: 2230±60 BP J3: (context 1342) Beta 48924: 2320±70 BP (context 1382) Beta 48923: 2140±70 BP J4: (context 1175) Beta 57701: 2380±70 BP (context 1291) Beta 48918: 2240±80 BP(context 1291) Beta 57702: 2300±90 BP (context 1236) Beta 48919: 2160±60 BP	*I1 - 8* Rectangular structures as living places (wattle and daub constructions. First phase probably roofed with grass or palm the later roofed with kiln-fired tiles). The settlement extent could be 60 to 100 hectares. Small furnace or an oven. Inscribed sherds. RLW, Sea shells, Mud or flip-shell turtle, Monitor, lizards and Coconut, coins I1 (context 1173) BM 2877: 2310±70 BP (context 1173) Beta 48925: 2150±50 BP I2 (context 1113) Beta 48926: 2150±60 BP (context 1112) Beta 48927: 2110±60 BP I3 (context 1097) Beta 48928: 2290±90 BP I4 (context 914) BM 2876: 2200±45 BP (context 905) Beta 48930: 2390±60 BP I5 (context 901) Beta 48931: 2320±60 BP I7 (context 834) Beta 48932: 2160±60 BP I8 (context 812) Beta 48933: 2220±80 BP (context 728) Beta 48934: 2000±80 BP .	Levelling or occupation floors, Brahmi sealing, Gray ware, Rouletted pottery, Hellenistic pottery, Pottery with Brahmi characters H (context 721) Beta 48935: 2230±90 BP (context 718) Beta 48936: 2280±70 BP (context 692) Beta 48937: 2250±60 BP (context 735) BM 2878: 1960±80 BP *Structural period G* **G2 - 5** First appearance of limestone slabs and brick as building material, range of tiled, white-washed and plastered wattle and daub structures, brick-paved lane (north-south). G2 (context 615) Beta 48938: 2130±60 BP G3 (context 632) Beta 48939: 1950±60 BP G2 (context 340) BM 2781: 1950±60 BP	Maneless lion coins, Lakshmi coins, Punch-mark coins, Tree and swastika coins, Late Roman Imperial Third –Brasses, Earthenware vessels. *Structural periods E,D,C and B* (Robber pits are visible) Ceramics ranging from Early Historic Period. Imported glass from east and Western Asia. Coarse gray stoneware. Glass sherds of Egyptian, Syrian and Persian provenance.

* Coningham's structural period A, containing a mixture of RLW, Western and East Asian pottery, modern bone China, a George VI coin of 1943, an metal tax sign of 1918 and an umbrella, is dated to the 1st half of the 20th century.

A.2. Sample catalogue

This catalogue contains detailed descriptions about building (n=38) and source rock (n=23) samples, which were considered to gain information about the origin and resource mobility in the ancient city of Anuradhapura. The catalogue consists of 61 pages allocating one page for one sample. Each page contains a location map, a short description of the historical background of the monument or quarry location and a petrological description of the rock, chemical and mineralogical data and pictures of the sample. The catalogue is sorted in alphabetical order of the sample name. The first two letters of the sample names indicate the originated location of the sample.

Table A.1.: Contents of the catalogue

Page	Sample	Location	Source	Rock type
XXIV	AB.03.Be.	Abhayagiriya	Ancient quarry	Granitic gneiss
XXV	AB.08.Be.	Abhayagiriya	Ancient quarry	Granitic gneiss
XXVI	AB.15.Be.	Abhayagiriya	Ancient quarry	Granitic gneiss
XXVII	AB.20.Be.	Abhayagiriya	Ancient quarry	Granitic gneiss
XXVIII	AB.21.Be.	Abhayagiriya	Ancient quarry	Granitic gneiss
XXIX	AB.22.Be.	Abhayagiriya	Ancient quarry	Granitic gneiss
XXX	AB.32.Be.	Abhayagiriya	Balustrade	Granitic gneiss
XXXI	AB.33.Bu.	Abhayagiriya	Foundation slab	Marble
XXXII	AB.34.Bu.	Abhayagiriya	External pillar	Granitic gneiss
XXXIII	AB.35.Bu.	Abhayagiriya	Flower offering slab	Marble
XXXIV	AB.36.Bu.	Abhayagiriya	Foundation slab	Marble
XXXV	AB.37.Bu.	Abhayagiriya	Foundation slab	Marble
XXXVI	AB.38.Bu.	Abhayagiriya	Foundation slab	Marble
XXXVII	AB.39.Bu.	Abhayagiriya	Internal pillar	Granitic gneiss
XXXVIII	BK.03.Be.	Basawakkulama	Ancient quarry	Granitic gneiss
XXXIX	BK.05.Be.	Basawakkulama	Ancient quarry	Granitic gneiss
XL	BK.09.Bu.	Basawakkulama	Foundation slab	Granitic gneiss
XLI	C.01.Bu.	Citadel	Guardstone	Granitic gneiss
XLII	C.02.Bu.	Citadel	External pillar	HBMG
XLIII	I.08.Be.	Isurumuniya	Ancient quarry	Granitic gneiss
XLIV	I.13.Be.	Isurumuniya	Ancient quarry	Granitic gneiss
XLV	J.01.Bu.	Jethavnaramaya	Foundation Slab	Marble
XLVI	J.02.Bu.	Jethavnaramaya	Rampart wall slab	Granitic gneiss
XLVII	J.03.Bu.	Jethavnaramaya	Rice boat	Granitic gneiss
XLVIII	KN.01.Be.	kanadarawa	Rock exposure	Marble
XLIX	MG.04.Be.	Medagama	Rock exposure	Marble
L	MG.06.Be.	Medagama	Rock exposure	Marble
LI	MG.11.Be.	Medagama	Rock exposure	Marble
LII	MR.01.Bu.	Mirisavetiya	Internal pillar	Granitic gneiss

LIII	MR.03.Be.	Mirisavetiya	Ancient quarry	Granitic gneiss
LIV	MR.04.Bu.	Mirisavetiya	Internal pillar	Granitic gneiss
LV	MR.05.Bu.	Mirisavetiya	Internal pillar	Granitic gneiss
LVI	VI.01.Bu.	Vijayaramaya	Buddha image	Marble
LVII	VI.02.Bu.	Vijayaramaya	Foundation slab	Marble
LVIII	VI.03.Bu.	Vijayaramaya	Dado slab	Granitic gneiss
LIX	VI.04.Bu.	Vijayaramaya	Foundation slab	Granitic gneiss
LX	V.01.Bu.	Vessagiriya	Balustrade	Marble
LXI	V.08.Bu.	Vessagiriya	Moonstone	Marble
LXII	V.10.Be.	Vessagiriya	Ancient quarry	Granitic gneiss
LXIII	V.16.Be.	Vessagiriya	Ancient quarry	Granitic gneiss
LXIV	V.19.Be.	Vessagiriya	Ancient quarry	Granitic gneiss
LXV	V.25.Be.	Vessagiriya	Ancient quarry	Granitic gneiss
LXVI	WM.03.Bu.	Western Monasteries	Dado slab	Granitic gneiss
LXVII	WM.04.Bu.	Western Monasteries	Building wall slab	Granitic gneiss
LXVIII	WM.07.Bu.	Western Monasteries	Ancient quarry	Granitic gneiss
LXIX	WM.08.Bu.	Western Monasteries	Rampart wall slab	Granitic gneiss
LXX	WM.09.Bu.	Western Monasteries	Rampart wall slab	Granitic gneiss
LXXI	WM.13.Be.	Western Monasteries	Ancient quarry	Granitic gneiss
LXXII	WM.16.Bu.	Western Monasteries	Building wall slab	Granitic gneiss
LXXIII	WM.17.Bu.	Western Monasteries	Dado slab	Granitic gneiss
LXXIV	WM.18.Bu.	Western Monasteries	Foundation slab	Granitic gneiss
LXXV	WM.19.Bu.	Western Monasteries	Foundation slab	Granitic gneiss
LXXVI	WM.23.Be.	Western Monasteries	Ancient quarry	HBMG
LXXVII	WM.24. Bu.	Western Monasteries	Foundation slab	Granitic gneiss
LXXVIII	WM.25.Bu.	Western Monasteries	Terrace wall slab	Granitic gneiss
LXXIX	WM.26.Bu.	Western Monasteries	Terrace wall slab	Granitic gneiss
LXXX	WM.27.Be.	Western Monasteries	Ancient quarry	Granitic gneiss
LXXXI	WM.29.Bu.	Western Monasteries	Terrace wall slab	Granitic gneiss
LXXXII	WM.30.Be.	Western Monasteries	Ancient quarry	Granitic gneiss
LXXXIII	WM.33.Bu.	Western Monasteries	Rampart wall slab	Granitic gneiss
LXXXIV	WM.34.Bu.	Western Monasteries	Rampart wall slab	Granitic gneiss

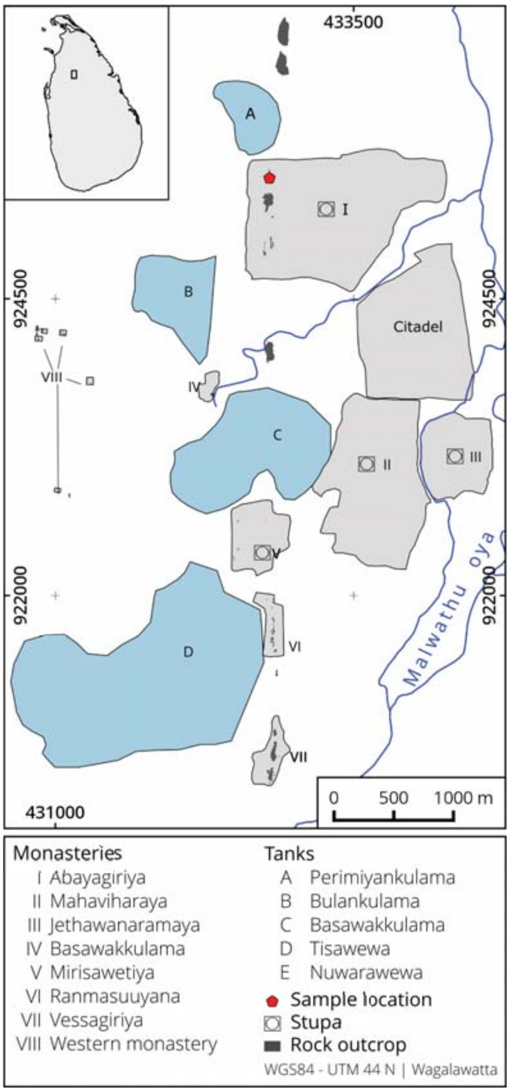
AB.03.Bu.

Abayagiriya Monastery
8°.22'.33" N / 80°.22'.38" E

Source - Ancient Quarry
Rock type - Granitic Gneiss

Historical Background

The site is a exposed basement rock area situated in the Abayagiriya monastery. Ancient chisel marks are existing through the quarried edges of the parent rock. Moreover, a relinquished line of drilled quarry holes is also visible on the surface. The Abayagiriya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.

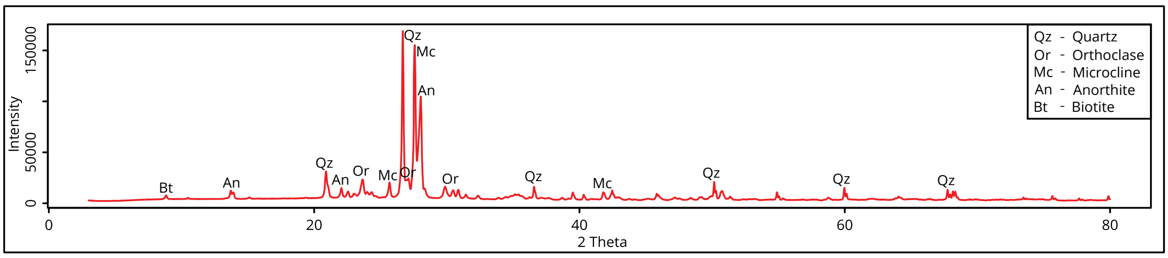


Rock Discription

The medium- to coarse-grained pink granitic gneiss is visually massive in nature. The rock contains pink coloured feldspars (orthoclase and microcline), colourless quartz and grey plagioclase. Biotite is the common mafic mineral in the rock.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.04	Co	0.01
TiO_2	0.30	V	0.01
Al_2O_3	12.94	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	3.39	Rb	0.02
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.33	Zr	0.03
K_2O	5.97	Nb	n.d.
P_2O_5	0.17	Ba	0.08
LOI	0.81	Ce	n.d.
Total	97.95		



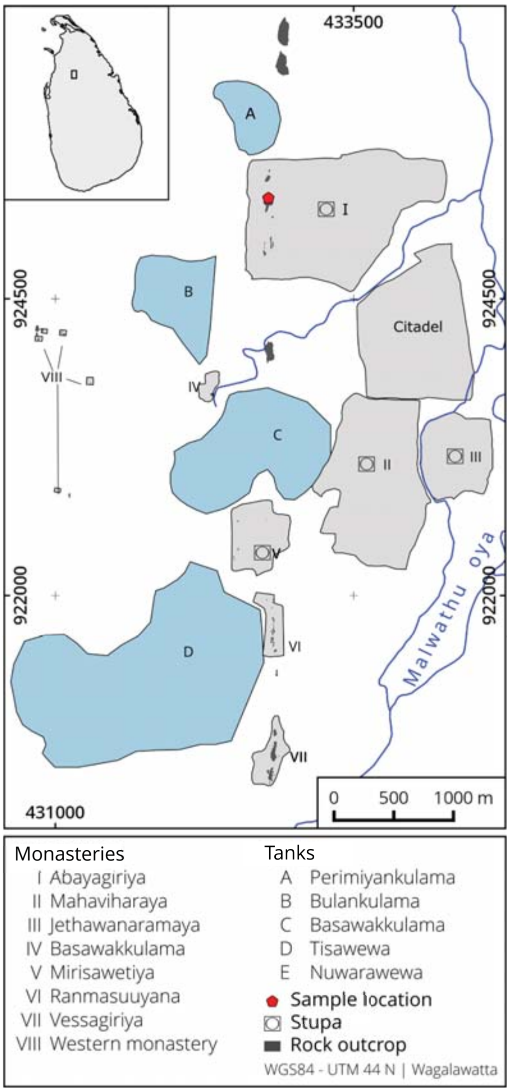
AB.08.Be. Abayagiriya Monastery

8°.22'.25" N / 80°.23'.37" E

Source - Ancient Quarry
Rock type - Granitic Gneiss

Historical Background

The site is a exposed rock boulder in the Abayagiriya monstery. Ancient chisel marks are existing through the quarried edges of the parent rock. Moreover, a relinquished line of drilled quarry holes is also visible on the surface. The Abayagiriya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.

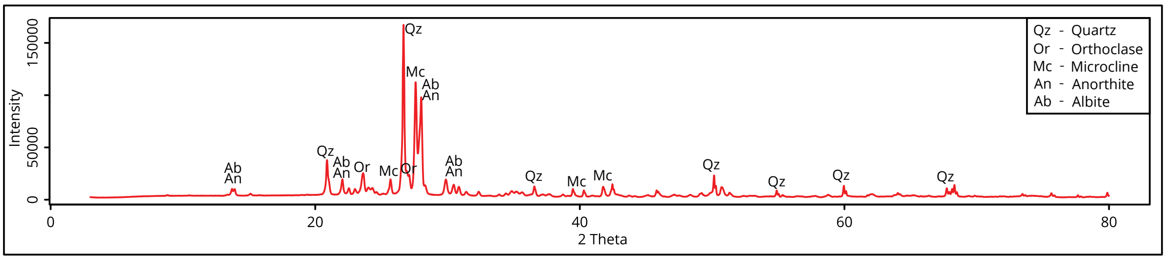


Rock Discription

Megascopically, the rock contains minerals of variable grain sizes (coarse to fine), as well as it contains feldspar, quartz, biotite and a minor amount of hornblende. In some places, the boulder contains two sets of joints.

Chemical Composition (n=1)

Major elements (wt.%)		Trace elements (ppm)	
SiO_2	73.37	Co	0.01
TiO_2	0.23	V	0.00
Al_2O_3	11.71	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.91	Rb	0.01
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.06	Zr	0.03
K_2O	5.65	Nb	n.d.
P_2O_5	0.16	Ba	0.09
LOI	0.17	Ce	n.d.
Total	94.25		



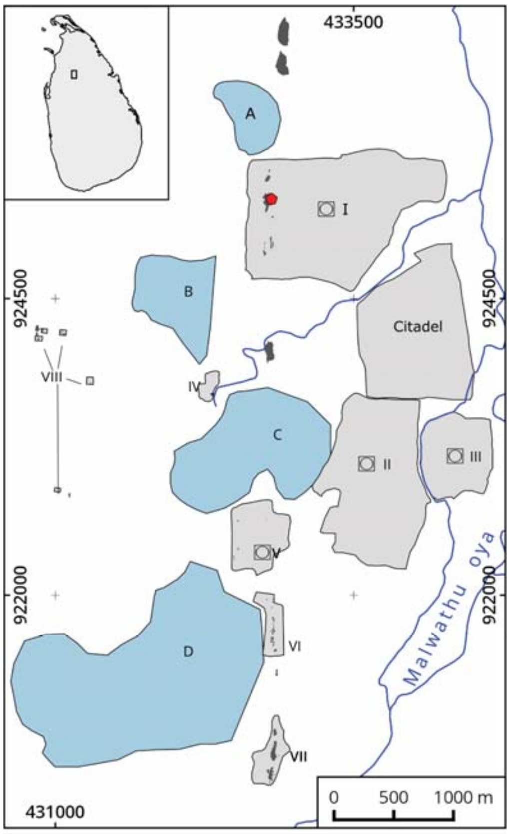
AB.15.Be.

Abayagiriya Monastery
8°.22'.27" N / 80°.23'.38" E

Source - Ancient Quarry
Rock type - Granitic Gneiss

Historical Background

The site is a exposed rock boulder situated in the Abayagiriya monastery. Ancient chisel marks are existing through the quarried edges of the parent rock. The Abayagiriya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.

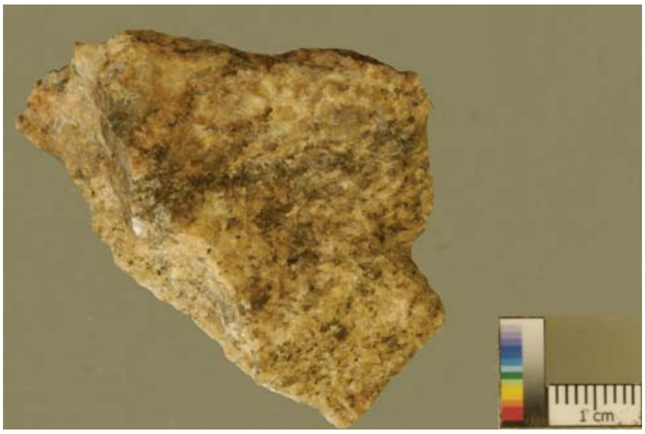


Monasteries	Tanks
I Abayagiriya	A Perimiyankulama
II Mahaviharaya	B Bulankulama
III Jethawanaramaya	C Basawakkulama
IV Basawakkulama	D Tisawewa
V Mirisawetiya	E Nuwarawewa
VI Ranmasuuyana	Sample location
VII Vessagiriya	Stupa
VIII Western monastery	Rock outcrop

WGS84 - UTM 44 N | Wagalawatta

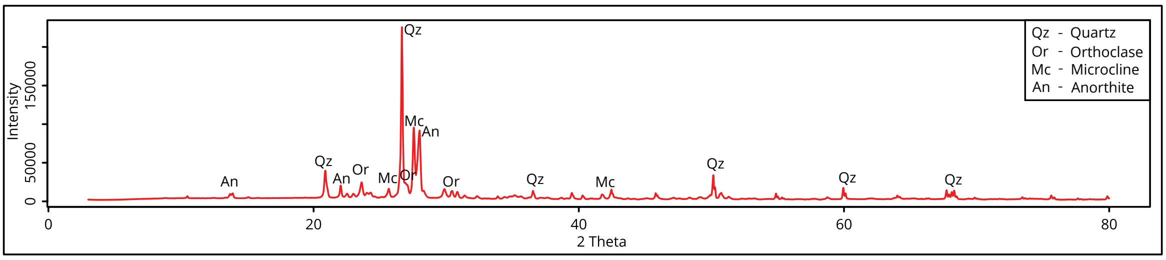
Rock Discription

The pink granitic gneiss shows slightly deformed fabric. Pegmatite patches and lenses are present. Weathered surfaces of the rock are mostly in white colour. Major rock-forming minerals are quartz and feldspar. However, variable amounts of biotite and hornblende are present.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	76.02	Co	0.01
TiO_2	0.21	V	0.00
Al_2O_3	11.54	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	2.12	Rb	0.02
MnO	n.d.	Sr	0.02
MgO	n.d.	Y	n.d.
CaO	1.36	Zr	0.00
K_2O	4.91	Nb	n.d.
P_2O_5	0.12	Ba	0.06
LOI	0.40	Ce	n.d.
Total	96.67		



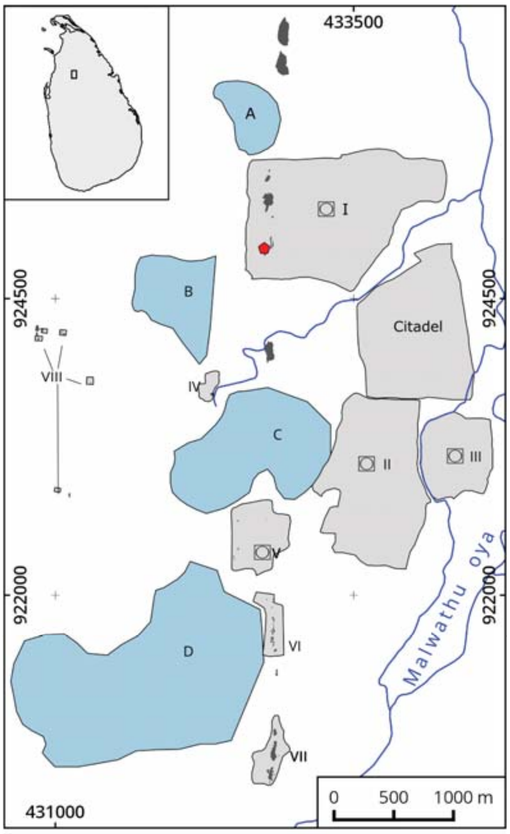
AB.20.Be. Abayagiriya Monastery

8°.22'.02" N / 80°.23'.35" E

Source - Ancient Quarry
Rock type - Granitic Gneiss

Hictorical Background

The site is a exposed boulder situated in the Abayagiriya monastery. Ancient chisel marks are existing through the quarried edges of the rock. The Abayagiriya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.



Monasteries
I Abayagiriya
II Mahaviharaya
III Jethawanaramaya
IV Basawakkulama
V Mirisawetiya
VI Ranmasuuyana
VII Vessagiriya
VIII Western monastery

Tanks
A Perimiyankulama
B Bulankulama
C Basawakkulama
D Tisawewa
E Nuwarawewa

Sample location
Stupa
Rock outcrop

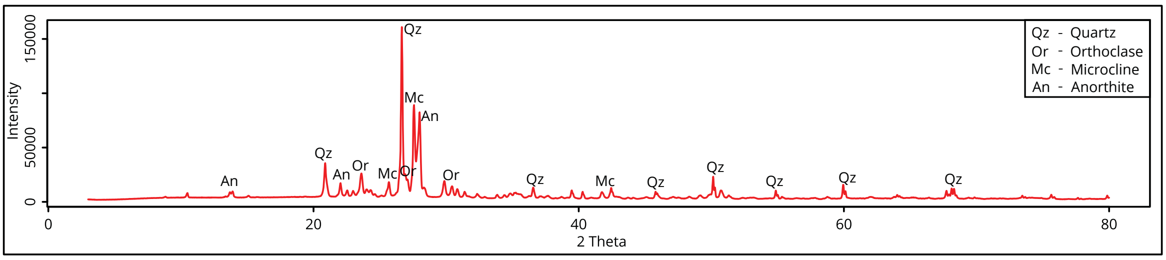
WGS84 - UTM 44 N | Wagalawatta

Rock Discription

The rock is a highly foliated granitic gneiss contains white to pink, unevenly medium to very coarse grains. K-feldspar (microcline and orthoclase), plagioclase (anorthite) and quartz with minor biotite and magnetite, hornblende are present.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	71.10	Co	0.01
TiO_2	0.26	V	0.01
Al_2O_3	10.98	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	2.69	Rb	0.01
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.39	Zr	0.03
K_2O	5.22	Nb	n.d.
P_2O_5	0.11	Ba	0.07
LOI	0.37	Ce	n.d.
Total	92.13		



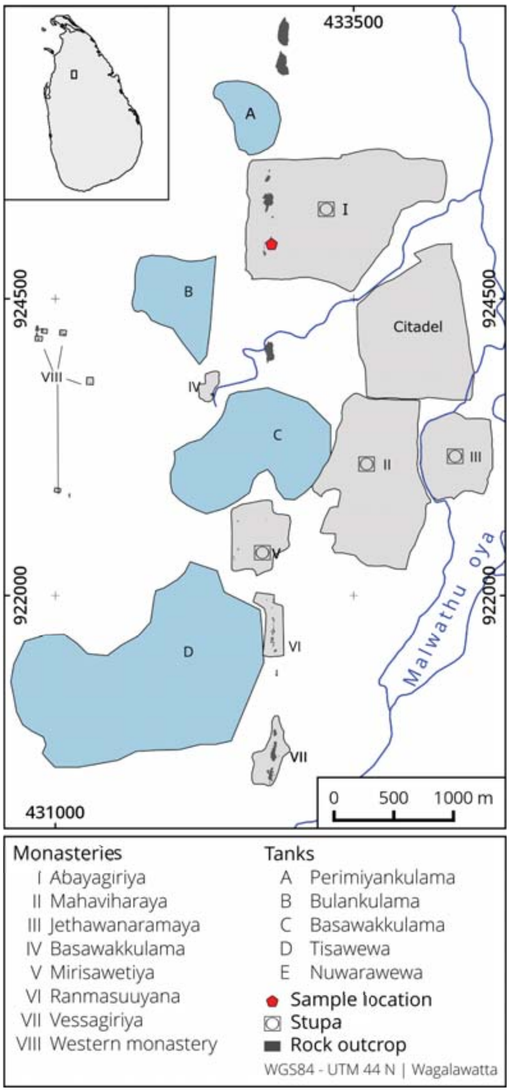
AB.21.Be.

Abayagiriya Monastery
8°.22'.02" N / 80°.23'.39" E

Source - Ancient Quarry
Rock type - Granitic Gneiss

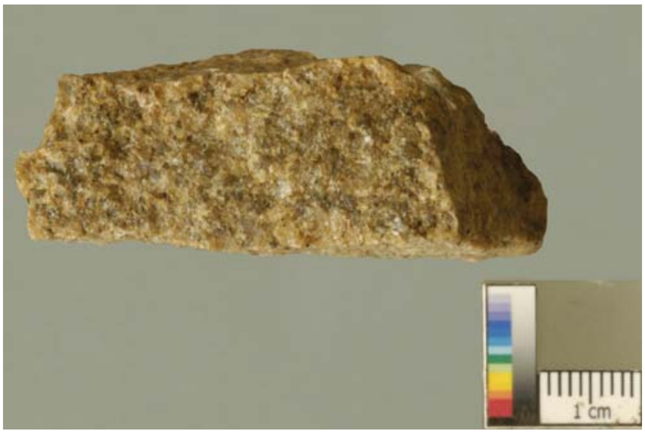
Historical Background

The site is a exposed boulder situated in the Abayagiriya monastery. Ancient chisel marks are existing through the quarried edges of the rock. The Abayagiriya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.



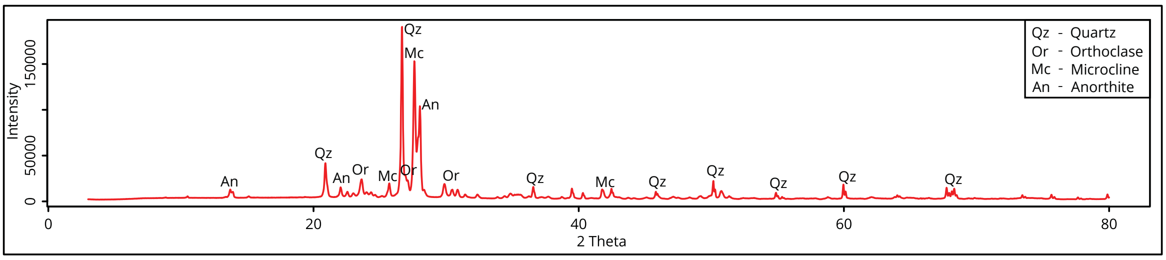
Rock Discription

The rock is pink coloured, medium grained and contains abundant quartz and feldspar. The dark minerals (biotite and hornblende) tend to occur in rather irregular splotchy clusters. Commonly the rock is strongly foliated by the alignment of both dark minerals.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.25	Co	0.01
TiO_2	0.20	V	0.01
Al_2O_3	11.86	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	2.54	Rb	0.01
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.11	Zr	0.04
K_2O	5.68	Nb	n.d.
P_2O_5	0.14	Ba	0.08
LOI	0.32	Ce	n.d.
Total	98.10		



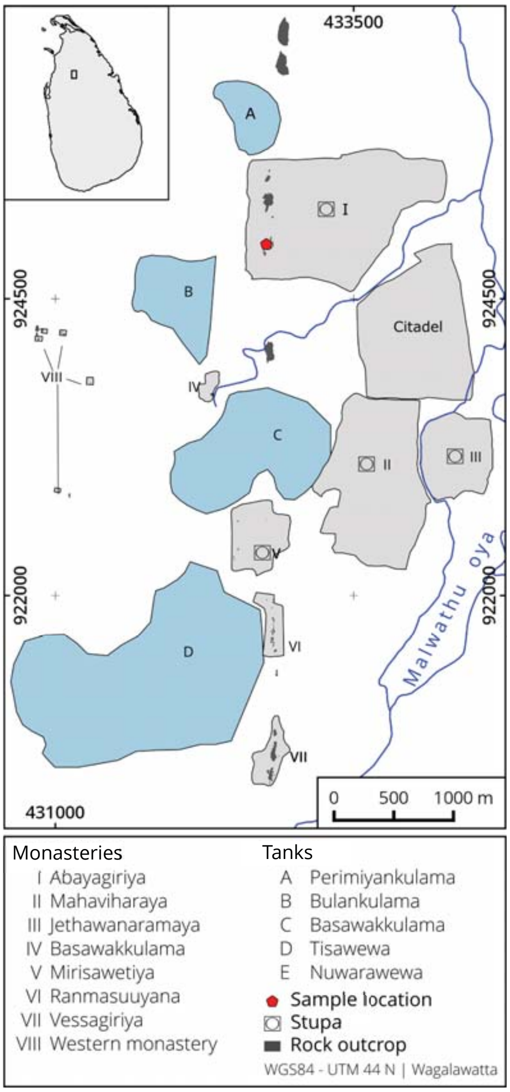
AB.22.Be. Abayagiriya Monastery

8°.22'.26" N / 80°.23'.37" E

Source - **Bedrock**
Rock type - **Granitic Gneiss**

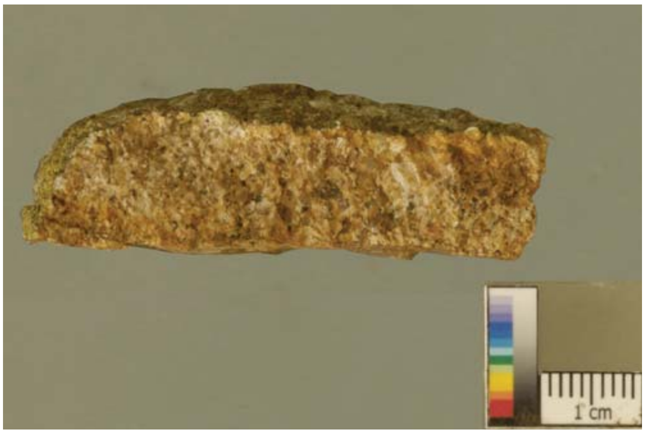
Historical Background

The quarry is located in the Abayagiriya monastery. The quarry space clearly indicates that ancient craftsmen extracted stone materials, creating a cave (rock cut cave) into the boulder; which is a rare situation in the ancient built environments of Sri Lanka. The Abayagiriya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.



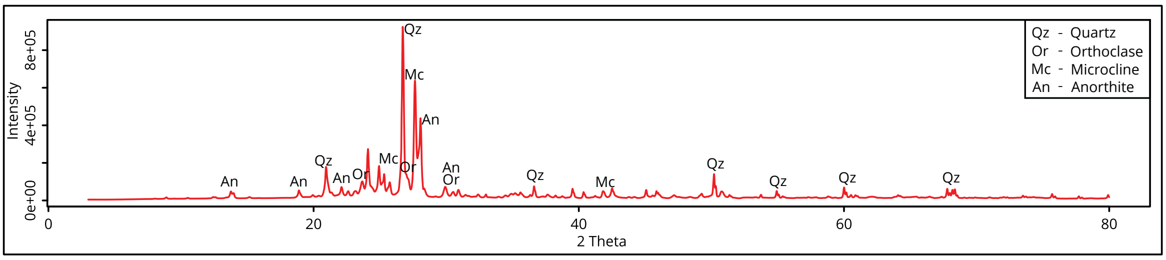
Rock Discription

The off-white to pink granitic rock is made up of typical granitic minerals with dark coloured biotite and hornblende. Foliation, appearance and locally visible variation indicate that the granitic boulders at the site are similar to many quarry sites in Anuradhapura.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	71.50	Co	0.01
TiO_2	0.19	V	0.00
Al_2O_3	10.09	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	2.55	Rb	0.02
MnO	n.d.	Sr	0.00
MgO	n.d.	Y	n.d.
CaO	0.83	Zr	0.02
K_2O	6.05	Nb	n.d.
P_2O_5	0.13	Ba	0.06
LOI	0.77	Ce	n.d.
Total	92.12		



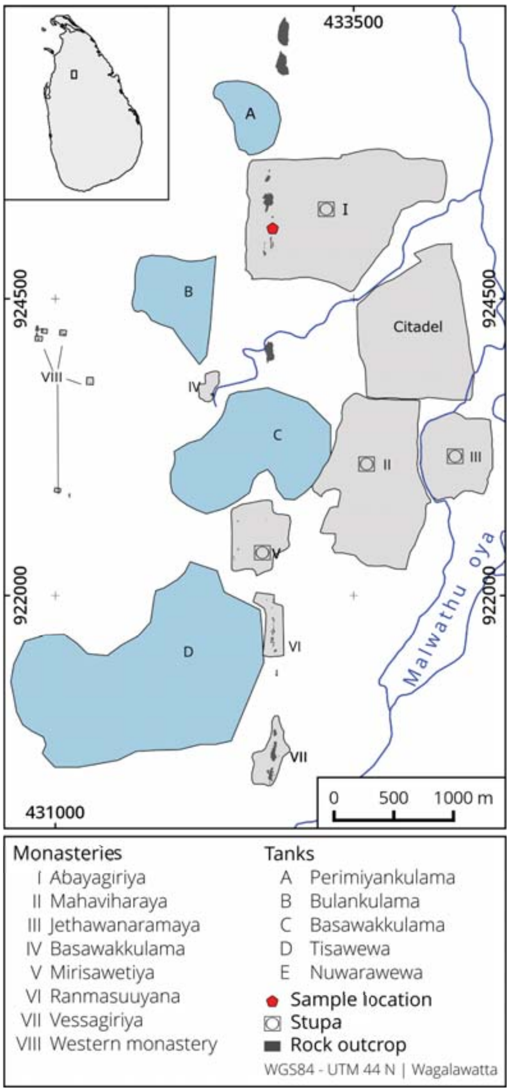
AB.32.Bu.

Abayagiriya Monastery
8°.22'.08" N / 80°.23'.34" E

Source - Building rock
Rock type - Granitic Gneiss

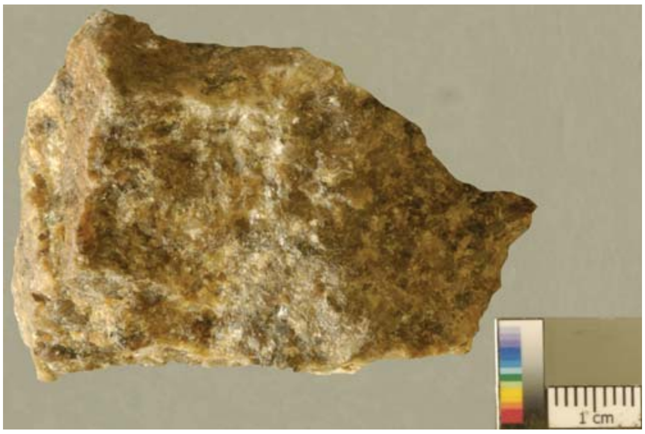
Historical Background

The sample originated from a balustrade in a ruined building of the Abayagiriya monastery. Balustrades are vertical stone slabs decorated with mythical or human figures. They are usually standing on both sides of the staircases. The Abayagiriya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.



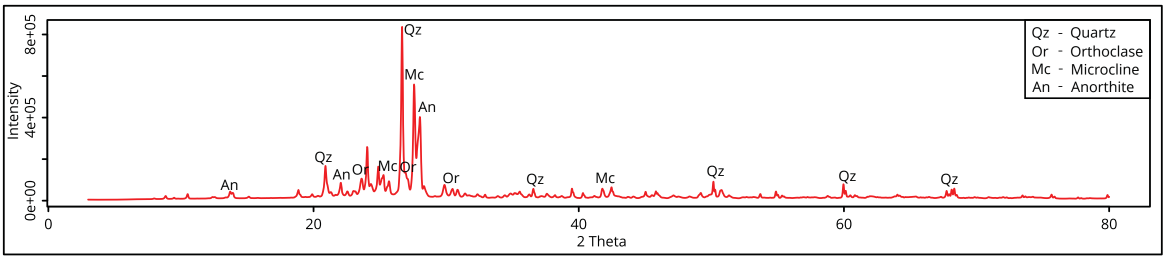
Rock Discription

Fine- to medium-grained less foliated rock contains quartz, orthoclase, microcline and plagioclase (anorthite) as major minerals. The content of biotite and hornblende is highly variable. Due to the weathering, the rock appears as greenish yellow colour.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.01	Co	0.01
TiO_2	0.20	V	0.01
Al_2O_3	11.01	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	0.41	Rb	0.01
MnO	n.d.	Sr	0.04
MgO	n.d.	Y	n.d.
CaO	0.96	Zr	0.04
K_2O	5.10	Nb	n.d.
P_2O_5	0.11	Ba	0.15
LOI	0.32	Ce	n.d.
Total	91.71		



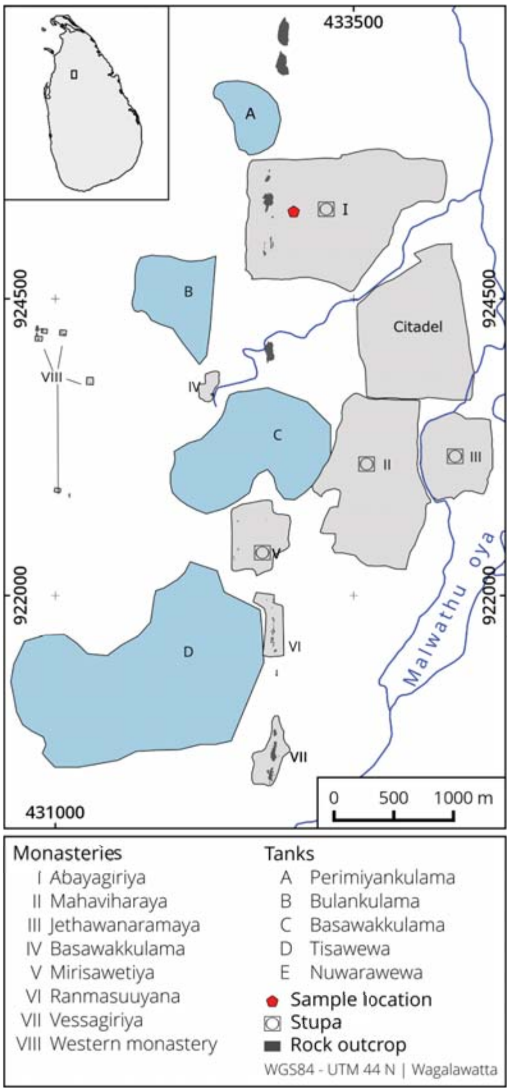
AB.33.Bu.

Abayagiriya Monastery
8°.22'.19" N / 80°.23'.49" E

Source - Building rock
Rock type - Marble

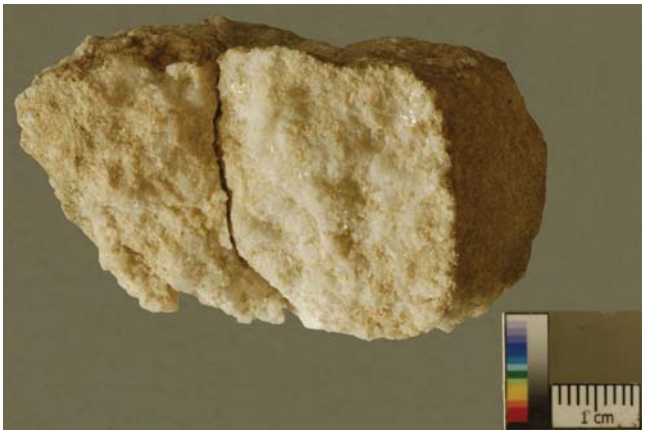
Historical Background

The sample originated from a foundation slab of an image house which is located in the Abayagiriya monastery. Only a few numbers of architectural features in the ancient built environment were constructed using marbles. These marble features are mostly available in sacred buildings. The Abayagiriya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.



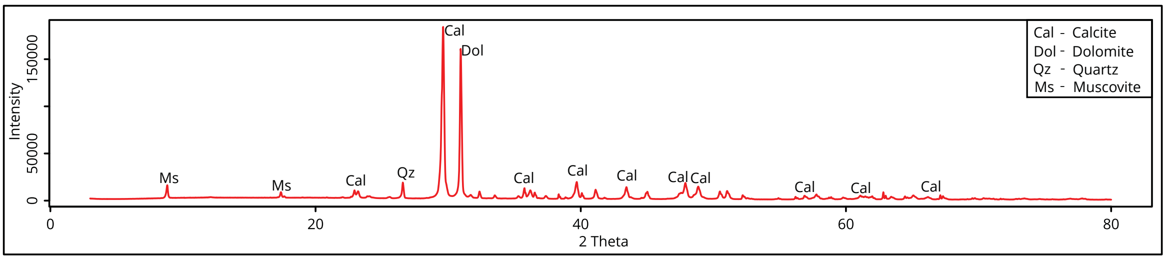
Rock Discription

Fine grained white coloured slightly weathered rock is made up mainly of calcite and dolomite. Secondary muscovite is the common disseminated mineral.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	9.08	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	5.14	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.52	Rb	n.d.
MnO	n.d.	Sr	0.01
MgO	13.50	Y	n.d.
CaO	35.56	Zr	n.d.
K_2O	0.24	Nb	n.d.
P_2O_5	0.52	Ba	0.04
LOI	18.93	Ce	n.d.
Total	83.50		



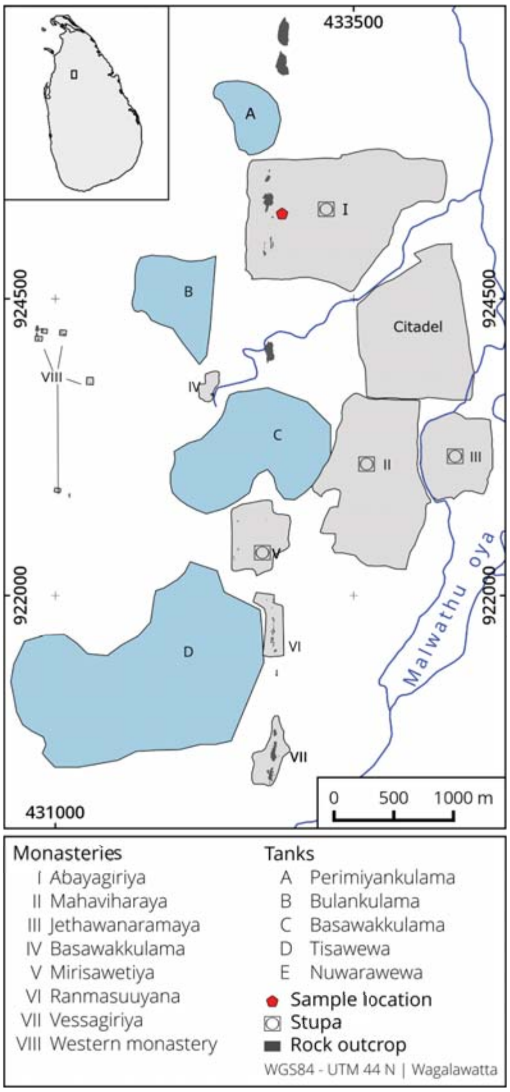
AB.34.Bu. Abayagiriya Monastery

8°.22'.15" N / 80°.23'.39" E

Source - **Building rock**
Rock type - **Granitic Gneiss**

Historical Background

The sample originated from an internal pillar in a ruined building in the Abayagiriya monastery. Stone pillars were used in two difierent ways in historic buildings; as internal pillars (roughly ffnished and positioned inside the brick walls) and external pillars (smoothly ffnished). The Abayagiriya is a major monastery includes difierent types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.

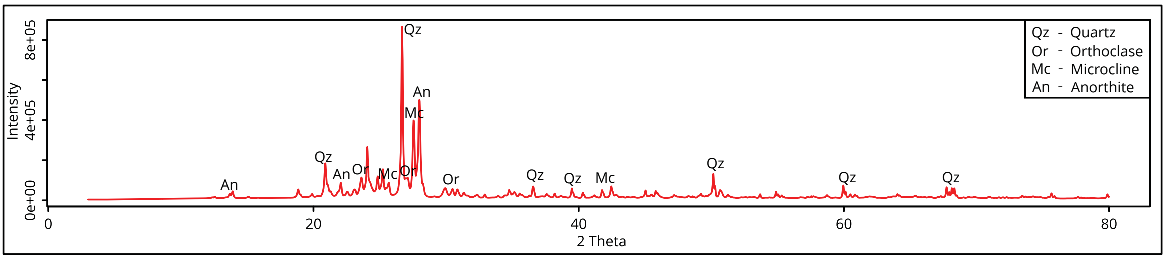


Rock Discription

The highly weathered rock of granitic gneiss contains quartz as the major mineral. Weathered feldspar and secondary mica are also present. Due to the intense weathering, the grains can easily be separated.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	72.87	Co	0.01
TiO_2	0.19	V	0.01
Al_2O_3	10.82	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.37	Rb	0.01
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	0.95	Zr	0.00
K_2O	5.12	Nb	n.d.
P_2O_5	0.10	Ba	0.15
LOI	0.30	Ce	n.d.
Total	92.13		



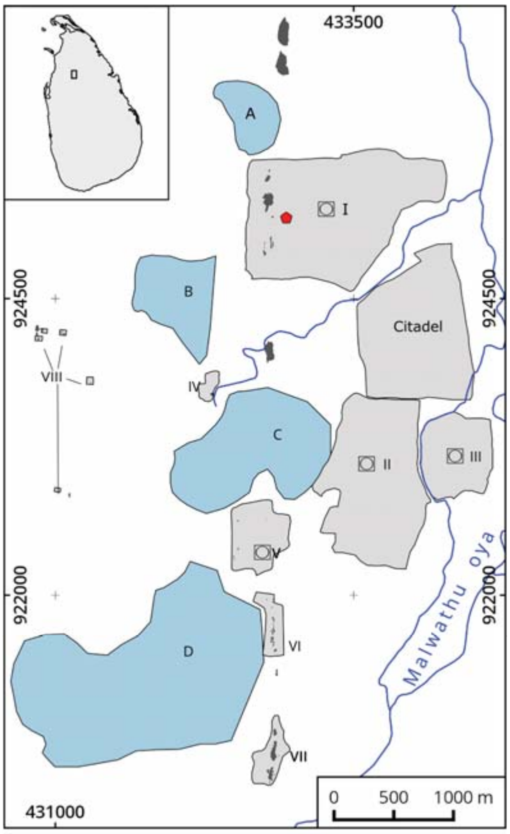
AB.35.Bu.

Abayagiriya Monastery
8°.22'.19" N / 80°.23'.45" E

Source - Building rock
Rock type - Marble

Historical Background

The sample originated from a foundation slab of an image house which is located in the Abayagiriya monastery. Only a few numbers of architectural features in the ancient built environment were constructed using marbles. These marble features are mostly available in sacred buildings. The Abayagiriya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.

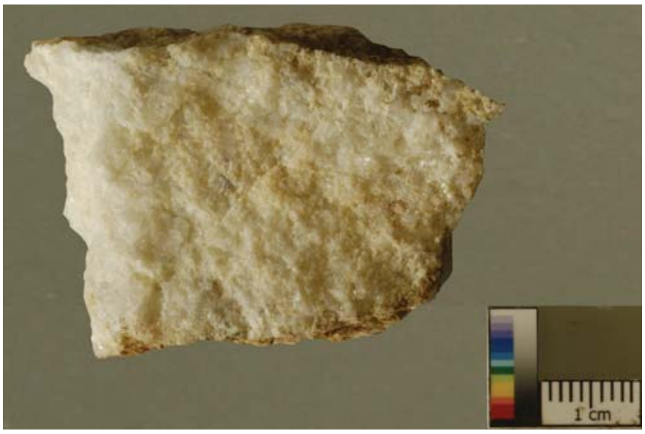


Monasteries		Tanks	
I	Abayagiriya	A	Perimiyankulama
II	Mahaviharaya	B	Bulankulama
III	Jethawanaramaya	C	Basawakkulama
IV	Basawakkulama	D	Tisawewa
V	Mirisawetiya	E	Nuwarawewa
VI	Ranmasuuyana		Sample location
VII	Vessagiriya		Stupa
VIII	Western monastery		Rock outcrop

WGS84 - UTM 44 N | Wagalawatta

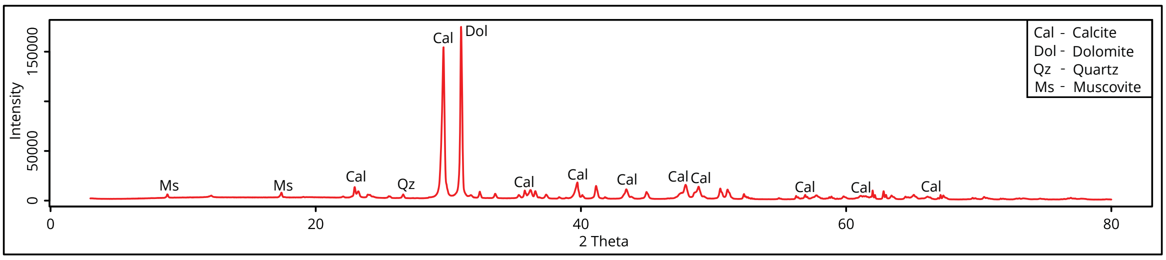
Rock Discription

The slightly weathered pure marble rock is made up of dolomite and calcite. Silicate minerals are rare. Muscovite is present as an accessory mineral.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	11.86	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	4.97	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.50	Rb	n.d.
MnO	n.d.	Sr	0.00
MgO	14.43	Y	n.d.
CaO	34.37	Zr	n.d.
K_2O	0.07	Nb	n.d.
P_2O_5	0.46	Ba	0.04
LOI	33.71	Ce	n.d.
Total	99.54		



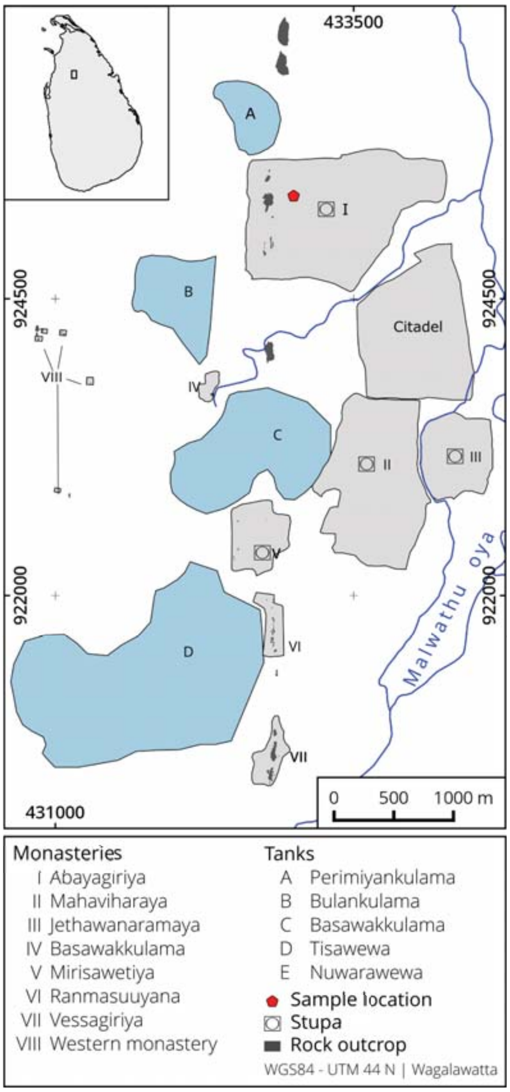
AB.36.Bu.

Abayagiriya Monastery
8°.22'.30" N / 80°.23'.51" E

Source - Building rock
Rock type - Marble

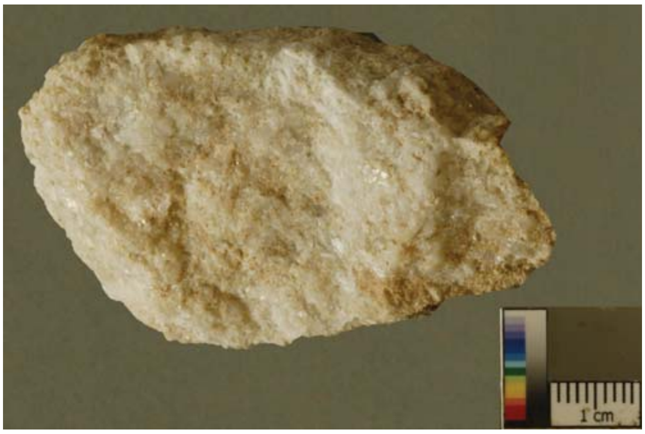
Historical background

The sample originated from a moulding slab of a ruined building which is located in the Abayagiriya monastery. Only a few numbers of architectural features in the ancient built environment were constructed using marbles. These marble features are mostly available in sacred buildings. The Abayagiriya is a major monastery includes difierent types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.



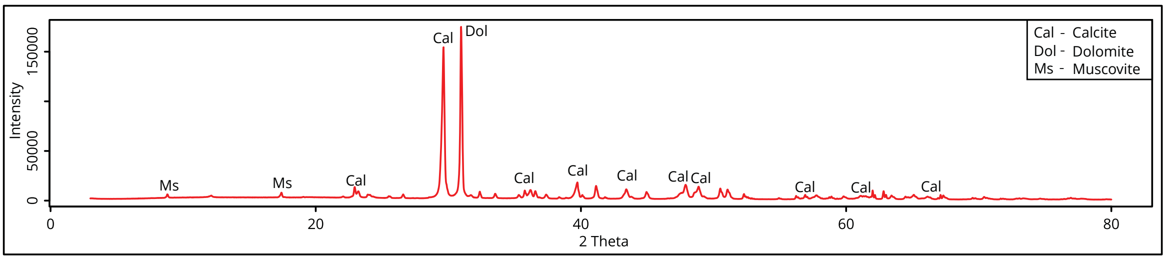
Rock Discription

The moderately weathered ffne-grained marble contains dolomite and calcite as rock forming minerals. Due to weathering, iron stains and altered mica are present.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	10.08	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	4.81	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.59	Rb	n.d.
MnO	n.d.	Sr	0.00
MgO	14.56	Y	n.d.
CaO	32.46	Zr	n.d.
K_2O	0.15	Nb	n.d.
P_2O_5	0.56	Ba	0.04
LOI	33.38	Ce	n.d.
Total	96.59		



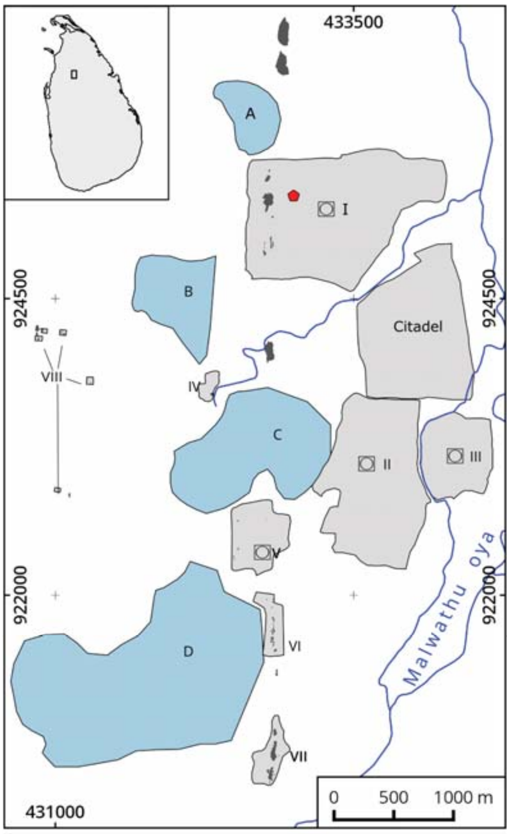
AB.37.Bu.

Abayagiriya Monastery
8°.22'.30" N / 80°.23'.51" E

Bource - building rock
Rock type - MarSle

Historical background

The sample originated from a moulding slab of a ruined building which is located in the Abayagiriya monastery. Only a few numbers of architectural features in the ancient built environment were constructed using marbles. These marble features are mostly available in sacred buildings. The Abayagiriya is a major monastery includes difierent types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.



Monasteries
I Abayagiriya
II Mahaviharaya
III Jethawanaramaya
IV Basawakkulama
V Mirisawetiya
VI Ranmasuuyana
VII Vessagiriya
VIII Western monastery

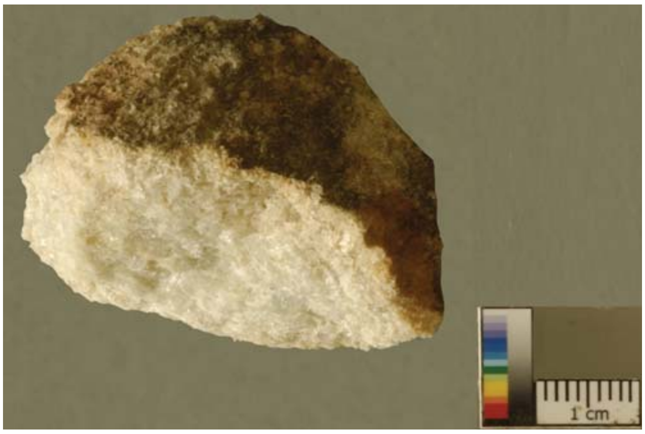
Tanks
A Perimiyankulama
B Bulankulama
C Basawakkulama
D Tisawewa
E Nuwarawewa

● Sample location
Stupa
Rock outcrop

WGS84 - UTM 44 N | Wagalawatta

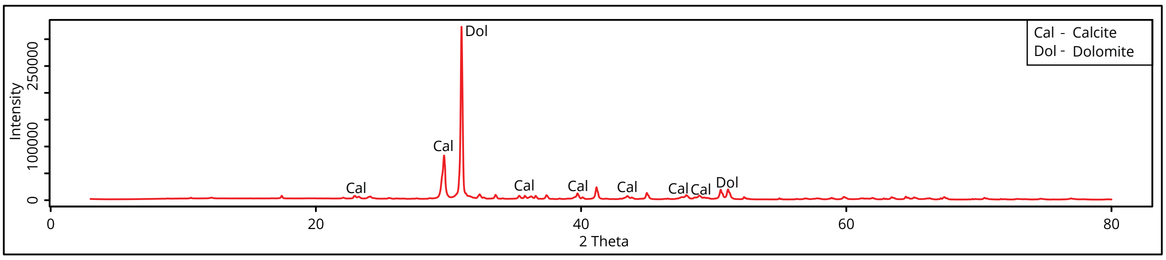
Rock Discription

The rock is slightly weathered, pure white coloured, ffne-grained dolomitic marble. It contains lesser amounts of disseminated silicate minerals.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	9.11	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	5.14	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.57	Rb	n.d.
MnO	n.d.	Sr	0.00
MgO	15.17	Y	n.d.
CaO	31.97	Zr	n.d.
K_2O	0.00	Nb	n.d.
P_2O_5	4.94	Ba	0.04
LOI	34.28	Ce	n.d.
Total	97.57		



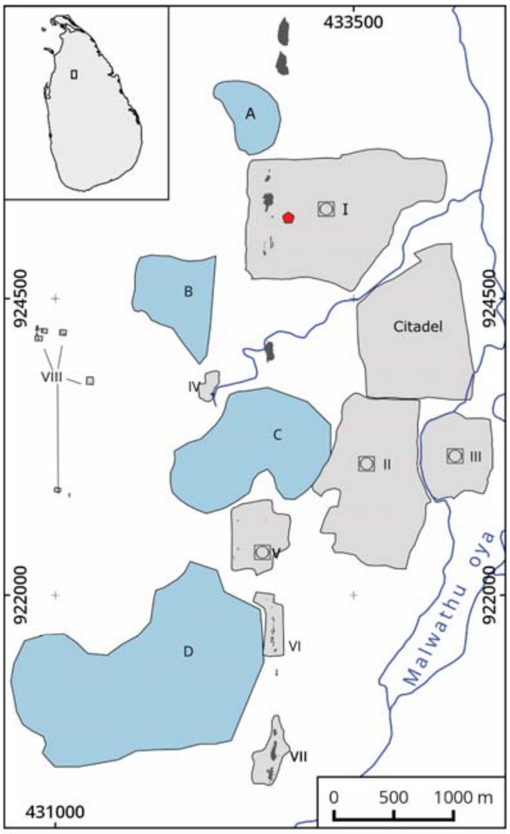
AB.36.Bu.

Abayagiriya Monastery
8°.22'.19" N / 80°.23'.49" E

Source - Building Rock
Rock type - Marble

Historical Background

The sample originated from a moulding slab of a ruined building which is located in the Abayagiriya monastery. Only a few numbers of architectural features in the ancient built environment were constructed using marbles. These marble features are mostly available in sacred buildings. The Abayagiriya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.



Monasteries
I Abayagiriya
II Mahaviharaya
III Jethawanaramaya
IV Basawakkulama
V Mirisawetiya
VI Ranmasuuyana
VII Vessagiriya
VIII Western monastery

Tanks
A Perimiyankulama
B Bulankulama
C Basawakkulama
D Tisawewa
E Nuwarawewa

Sample location
Stupa
Rock outcrop

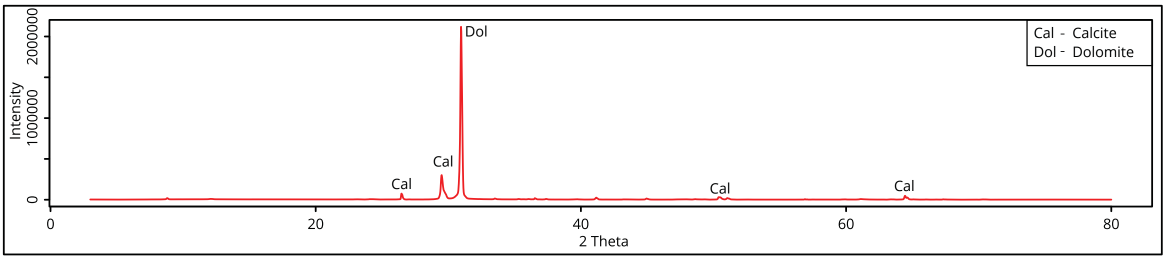
WGS84 - UTM 44 N | Wagalawatta

Rock Discription

The highly weathered medium grained marble is made up of calcite and dolomite. Secondary carbonates and muscovite mica are also present as accessory minerals.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	8.97	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	1.33	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.55	Rb	n.d.
MnO	n.d.	Sr	0.01
MgO	15.25	Y	n.d.
CaO	31.12	Zr	n.d.
K_2O	0.15	Nb	n.d.
P_2O_5	1.30	Ba	0.04
LOI	33.29	Ce	n.d.
Total	94.88		



AB.39.Bu.

Abayagiriya Monastery
8°.22'.27" N / 80°.23'.46" E

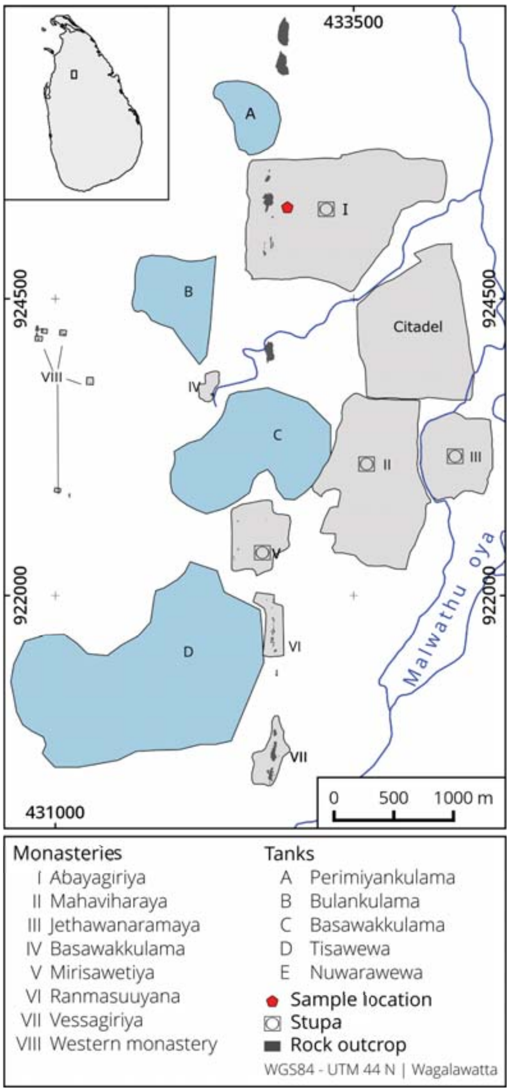
Source - Building rock
Rock type - Granitic Gneiss

Historical Background

The sample originated from an internal pillar in a ruined building which is located in the Abayagiriya monastery. Stone pillars were used in two different ways in historic buildings; as internal pillars (roughly finished and positioned inside the brick walls) and external pillars (smoothly finished). The Abayagiriya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.

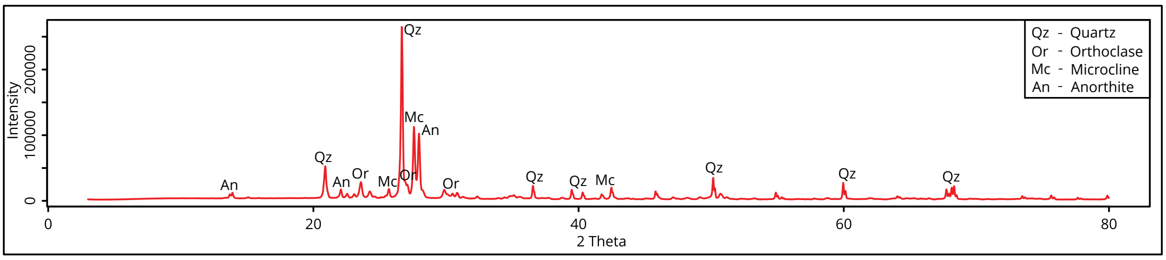
Rock Discription

The rock is fine- to medium grained granitic gneiss. Due to the intense weathering, the colour of the fresh rock has already been altered. Rock-forming minerals are quartz, orthoclase and microcline with minor plagioclase (anorthite) and biotite.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	81.87	Co	0.02
TiO_2	0.07	V	0.00
Al_2O_3	9.39	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	1.34	Rb	0.02
MnO	n.d.	Sr	0.00
MgO	n.d.	Y	n.d.
CaO	0.39	Zr	0.02
K_2O	4.91	Nb	n.d.
P_2O_5	0.10	Ba	0.04
LOI	0.13	Ce	n.d.
Total	97.79		



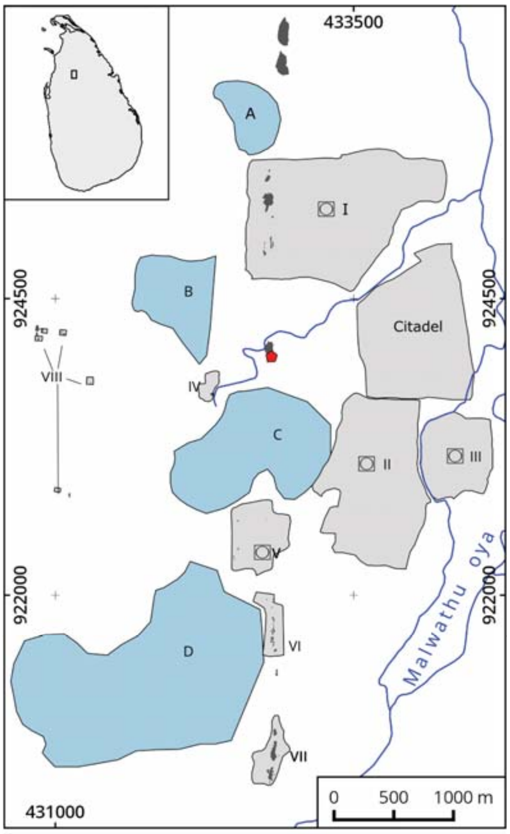
BK.03.Be. Basawakkulama Monastery

8°.21'.52" N / 80°.23'.38" E

Source - Ancient Quarry
Rock type - Granitic Gneiss

Historical Background

The site is a exposed boulder situated in the near vicinity of Basawakkulama monastery and tank. Ancient chisel marks are existing through the quarried edges of the rock. Moreover, a relinquished line of drilled quarry holes is visible on the boulder.



Monasteries		Tanks	
I	Abayagiriya	A	Perimiyankulama
II	Mahaviharaya	B	Bulankulama
III	Jethawanaramaya	C	Basawakkulama
IV	Basawakkulama	D	Tisawewa
V	Mirisawetiya	E	Nuwarawewa
VI	Ranmasuuyana		Sample location
VII	Vessagiriya		Stupa
VIII	Western monastery		Rock outcrop

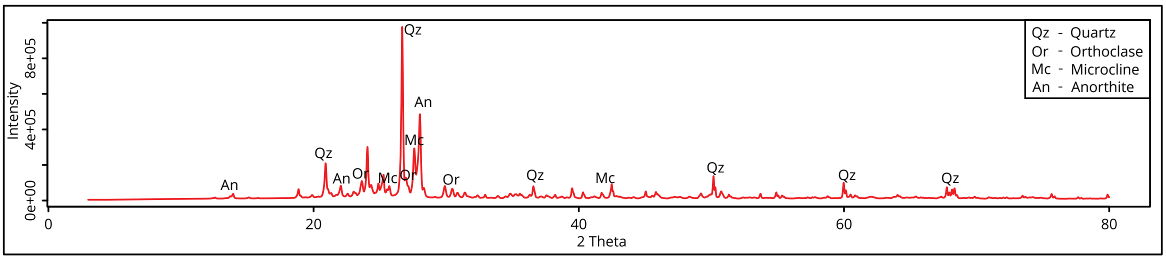
WGS84 - UTM 44 N | Wagalawatta

Rock Discription

The rock is a fine-to-medium-grained and foliated rock. The white bands of the rock are coarser grained and very poor in mafic minerals. Major rock forming minerals are quartz, orthoclase and plagioclase. Dark layers of the rock are rich in biotite and hornblende.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.76	Co	0.01
TiO_2	0.22	V	0.01
Al_2O_3	11.25	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	2.36	Rb	0.02
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.23	Zr	0.03
K_2O	5.57	Nb	n.d.
P_2O_5	0.16	Ba	0.07
LOI	0.50	Ce	n.d.
Total	94.05		



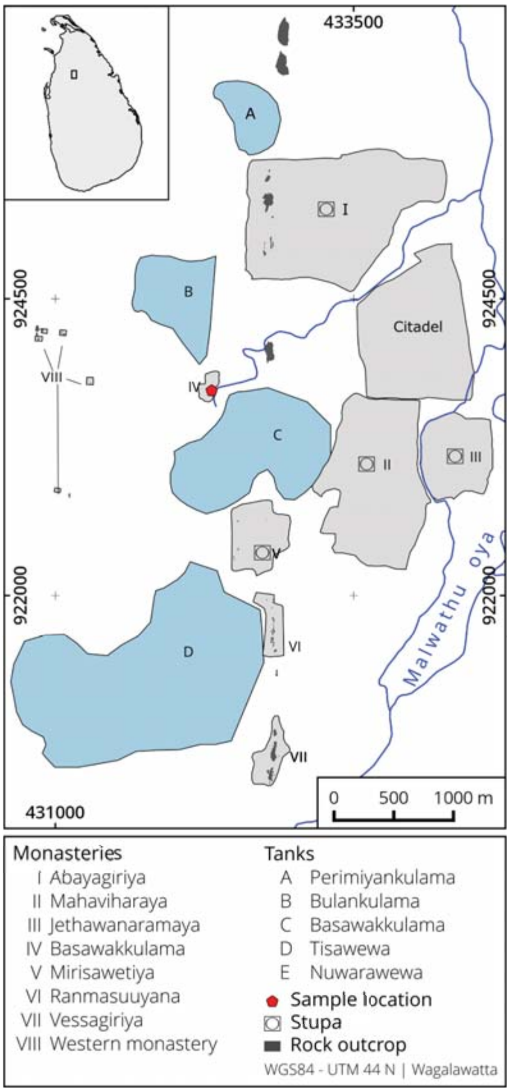
BK.05.Be. Basawakkulama Monastery

8°.21'.35" N / 80°.23'.11" E

Source - Ancient quarry
Rock type - Granitic Gneiss

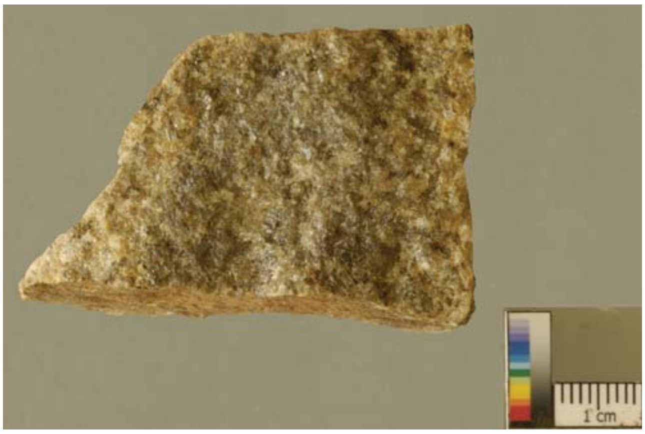
Historical Background

The site is a exposed boulder situated in the Basawakkulama (Abayawewa) monastery. Ancient chisel marks are existing through the quarried edges of the rock. However, the ancient quarry evidence were partly destroyed due to the modern human activities.



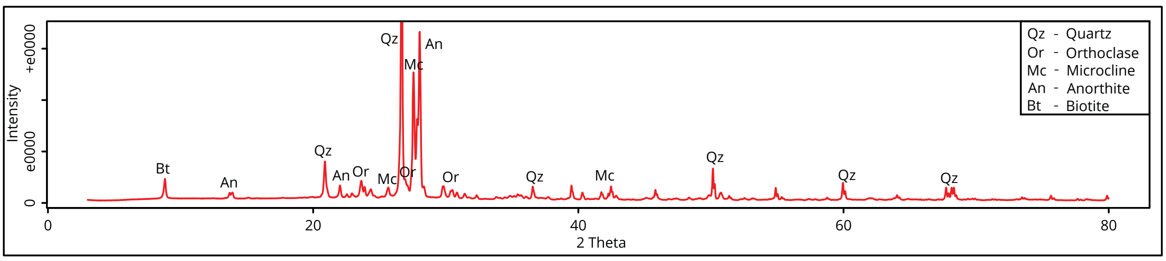
Rock Discription

This is a fine-to-medium-grained less foliated rock. Rock forming minerals are quartz, orthoclase, microcline and plagioclase. Mafic minerals such as biotite mica and hornblende are present as minor to accessory minerals.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	70.73	Co	0.01
TiO_2	0.18	V	0.00
Al_2O_3	12.54	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.75	Rb	0.00
MnO	n.d.	Sr	0.05
MgO	n.d.	Y	n.d.
CaO	3.34	Zr	0.01
K_2O	1.11	Nb	n.d.
P_2O_5	0.16	Ba	0.05
LOI	0.74	Ce	n.d.
Total	90.54		



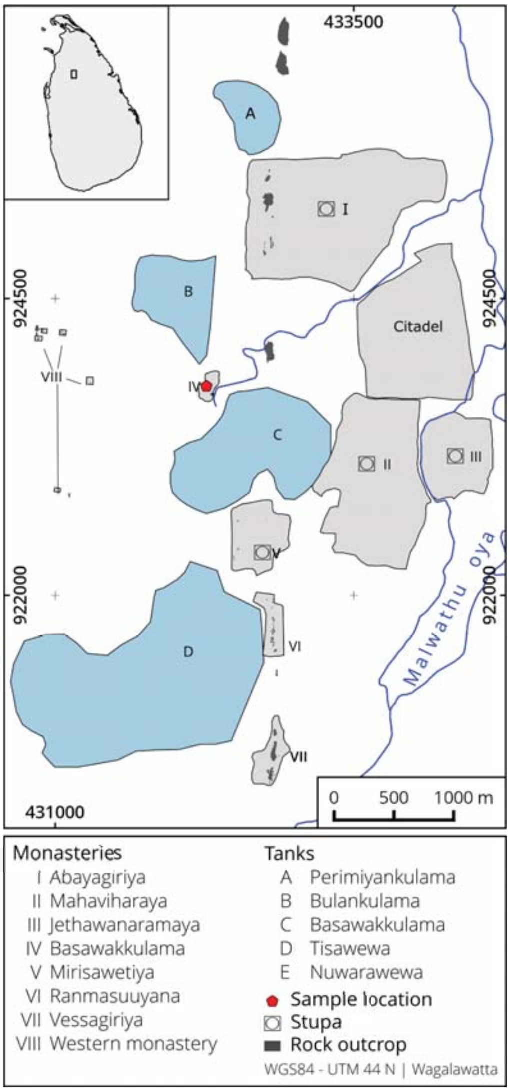
BK.09.Bu. Basawakkulama Monastery

8°.21'.40" N / 80°.23'.11" E

Source - Building rock
Rock type - Granitic Gneiss

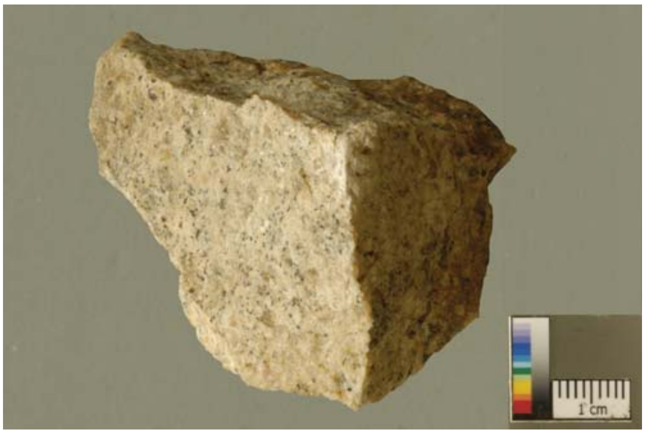
Historical Background

The sample originated from a foundation slab in a ruined building which is located in the Basawakkulama monastery. The Basawakkulama monastery is a minor monastery situated on the west side of the Basawakkulama tank (Abayawewa). The fewer number of ruined structures are visible in the monastery.



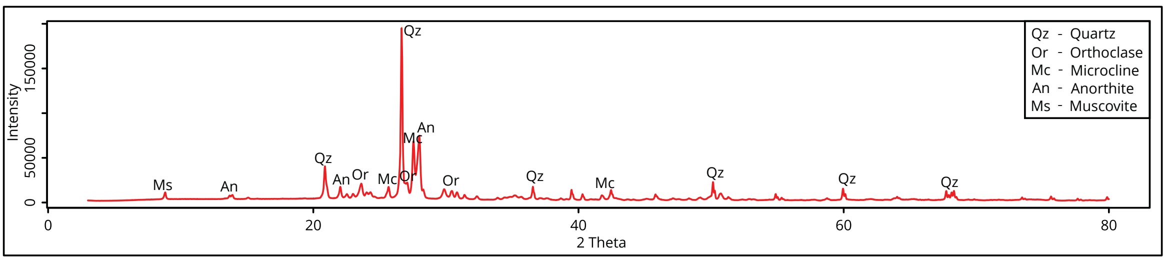
Rock Discription

This is a fine- to medium-grained light pink coloured rock, made up mainly of quartz and orthoclase with minor plagioclase. Minor to accessory amounts of biotite and muscovite mica are present.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	76.22	Co	0.02
TiO_2	0.13	V	0.01
Al_2O_3	11.31	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.55	Rb	0.02
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.09	Zr	0.02
K_2O	5.29	Nb	n.d.
P_2O_5	0.12	Ba	0.02
LOI	0.35	Ce	n.d.
Total	97.06		



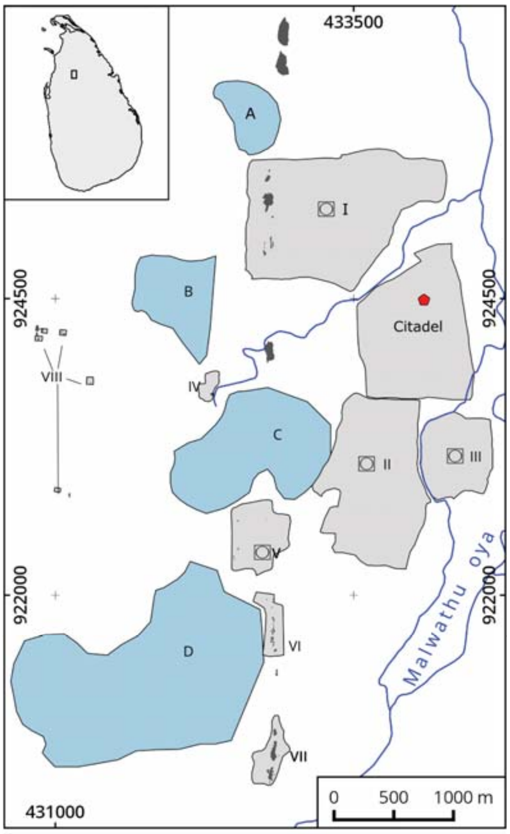
C.01.Bu.

Citadel
8°.21'.85" N / 80°.24'.15" E

Source - Building rock
Rock type - Granitic gneiss

Historical Background

The sample originated from a guardstone in a ruined building which is located in the Citadel. Guardstones are vertical stone slabs which are decorated with mythical or human figures, usually standing on both sides of the entrance of the buildings. The Citadel is the central settlement of ancient Anuradhapura, surrounded by a rampart and water moat.



Monasteries
I Abayagiriya
II Mahaviharaya
III Jethawanaramaya
IV Basawakkulama
V Mirisawetiya
VI Ranmasuuyana
VII Vessagiriya
VIII Western monastery

Tanks
A Perimiyankulama
B Bulankulama
C Basawakkulama
D Tisawewa
E Nuwarawewa

Sample location
Stupa
Rock outcrop

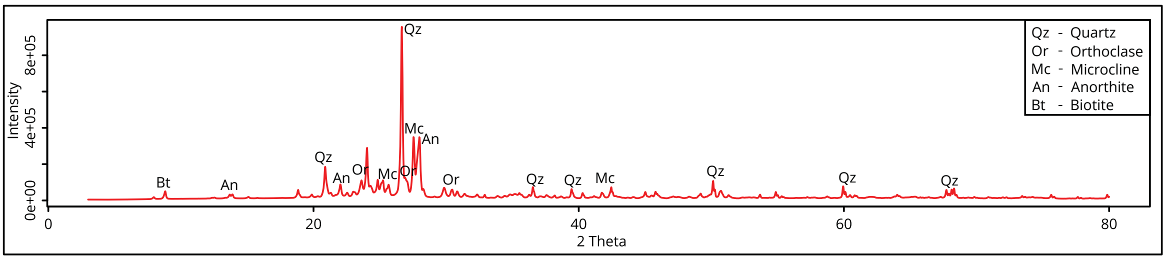
WGS84 - UTM 44 N | Wagalawatta

Rock Discription

The moderately weathered fine- to medium-grained granitic gneiss contains typical minerals of granite. Minor biotite is disseminated throughout the rock. Gneissic appearance is poorly defined in the rock.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	75.66	Co	0.02
TiO_2	0.14	V	0.01
Al_2O_3	11.21	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	3.59	Rb	0.02
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.20	Zr	0.01
K_2O	5.11	Nb	n.d.
P_2O_5	0.10	Ba	0.07
LOI	0.27	Ce	n.d.
Total	95.29		



C.02.Bu.

Citadel

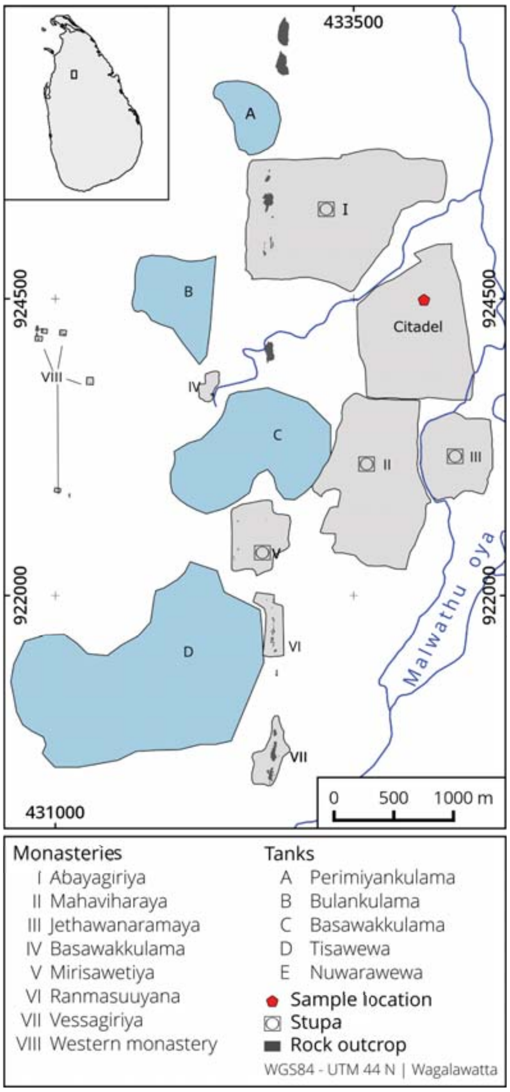
8°.21'.85" N / 80°.24'.15" E

Source - Building rock

Rock type - Magmatic Hornblende Biotitic Gneiss

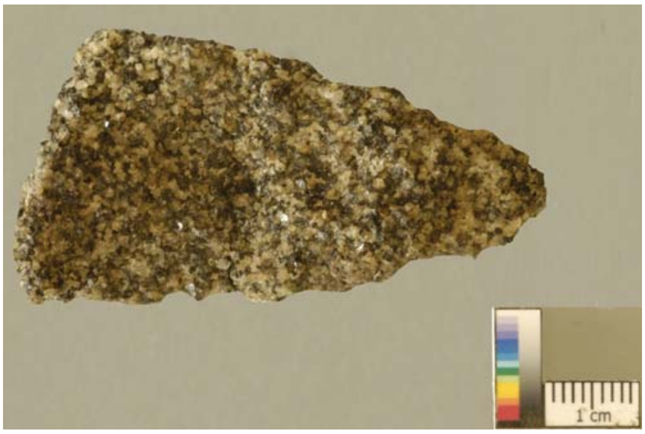
Historic Background

The sample originated from an internal pillar in a ruined building which is located in the Citadel. Stone pillars were used in two difierent ways in historic buildings; as internal pillars (roughly ffnished and positioned inside the brick walls) and external pillars (smoothly ffnished). The Citadel is the central settlement of ancient Anuradhapura, surrounded by a rampart and water moat.



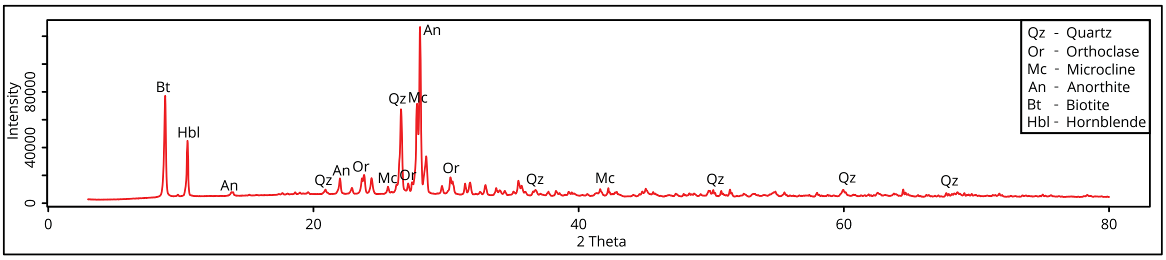
Rock Discription

The dark coloured rock is made mainly of medium-grained quartz, plagioclase, biotite and hornblende. Unlike granitic gneiss in the area, strongly developed foliation is present.



Chemical Composition (n=1)

Major elements (wt.%)		Trace elements (ppm)	
SiO_2	49.02	Co	0.00
TiO_2	1.25	V	0.01
Al_2O_3	16.04	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	10.05	Rb	0.01
MnO	n.d.	Sr	0.04
MgO	n.d.	Y	n.d.
CaO	6.77	Zr	0.02
K_2O	2.57	Nb	n.d.
P_2O_5	0.46	Ba	0.08
LOI	0.32	Ce	n.d.
Total	87.06		



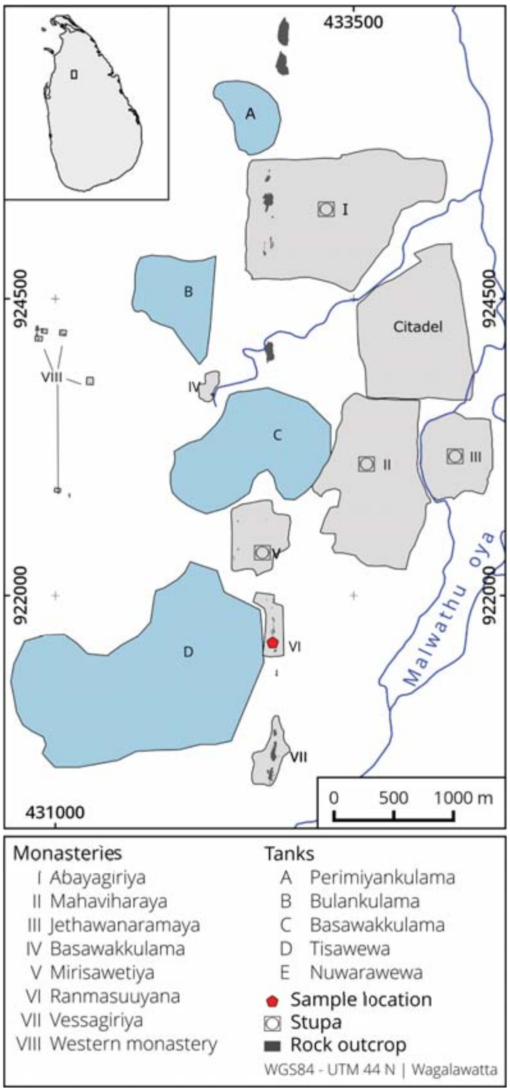
I.08.Be. Isurumuniya Monastery

8°.20'.20" N / 80°.23'.40" E

Source - Ancient quarry
Rock type - Granitic gneiss

Historical Background

The site is a exposed boulder situated in the Ranmasuuyana. Ancient chisel marks are existing through the quarried edges of the rock. Only the top level of the boulder was quarried and smoothly terraced. Four squared postholes also occur on the four corners of the terrace. Ranmasu uyana is a remarkable example of ancient Singhalese garden architecture. The garden is located adjacent to the Isurumuniya monastery and Thisawewa.

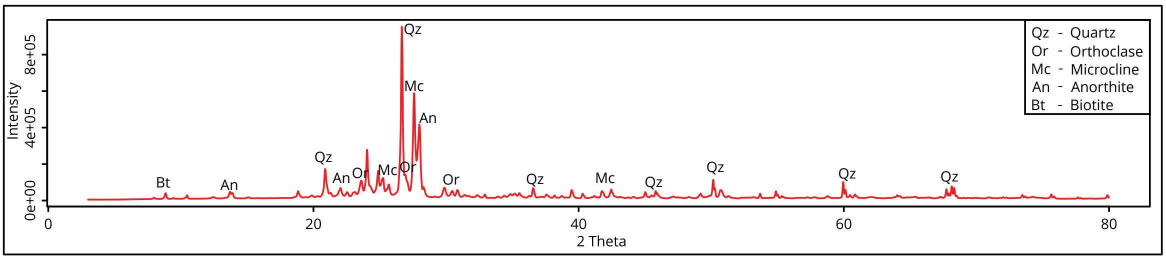


Rock Discription

Megascopically, the rock is fine- to coarse-grained. The large amounts of quartz and K-feldspar are present. Plagioclase, biotite and magnetite are accessory minerals.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	74.14	Co	0.01
TiO_2	0.24	V	0.01
Al_2O_3	10.86	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	2.61	Rb	0.02
MnO	n.d.	Sr	0.00
MgO	n.d.	Y	n.d.
CaO	1.14	Zr	0.03
K_2O	5.45	Nb	n.d.
P_2O_5	0.08	Ba	0.08
LOI	0.38	Ce	n.d.
Total	94.90		



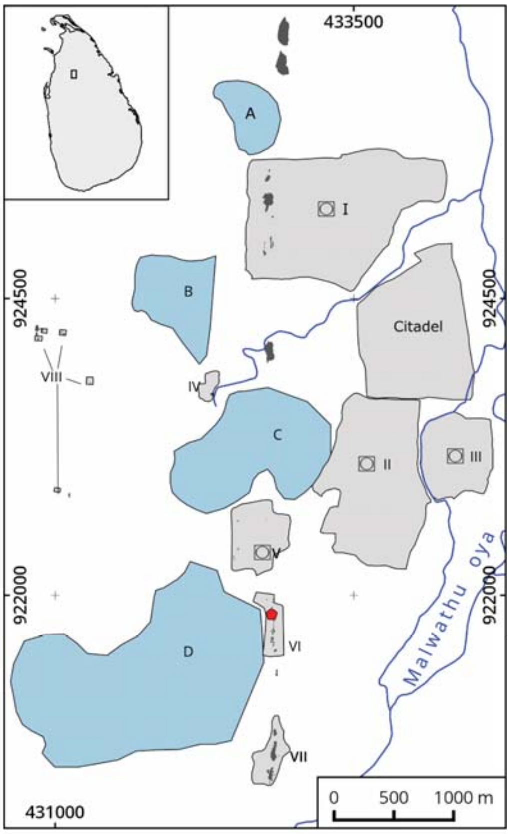
I.13.Be. Isurumuniya Monastery

8°.20'.42" N / 80°.23'.37" E

Source - Ancient quarry
Rock type - Granitic gneiss

Historical Background

The site is a exposed boulder situated in the Ranmasuuyana. Ancient chisel marks are existing through the quarried edges of the rock. Moreover, a relinquished line of drilled quarry holes is visible on the boulder. Ranmasu uyana is a remarkable example of ancient Singhalese garden architecture. The garden is located adjacent to the Isurumuniya monastery and Thisawewa.

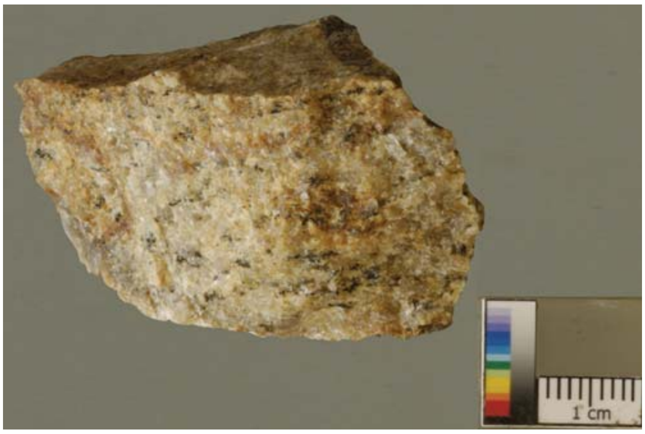


Monasteries	Tanks
I Abayagiriya	A Perimiyankulama
II Mahaviharaya	B Bulankulama
III Jethawanaramaya	C Basawakkulama
IV Basawakkulama	D Tisawewa
V Mirisawetiya	E Nuwarawewa
VI Ranmasuuyana	Sample location
VII Vessagiriya	Stupa
VIII Western monastery	Rock outcrop

WGS84 - UTM 44 N | Wagalawatta

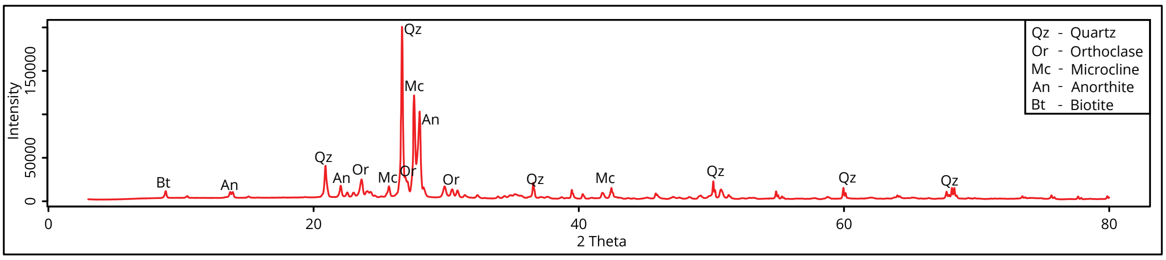
Rock Discription

The pinkish brown coloured rock contains gneissic fabrics. Some pegmatite patches are also present in the rock. Weathered surface of granite shows different coloured bands.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.38	Co	0.01
TiO_2	0.18	V	0.01
Al_2O_3	11.37	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	2.16	Rb	0.02
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.15	Zr	0.02
K_2O	5.26	Nb	n.d.
P_2O_5	0.10	Ba	0.07
LOI	0.39	Ce	n.d.
Total	93.98		



J.01.Bu. Jethawanarama Monastery

8°.20'.99" N / 80°.24'.29" E

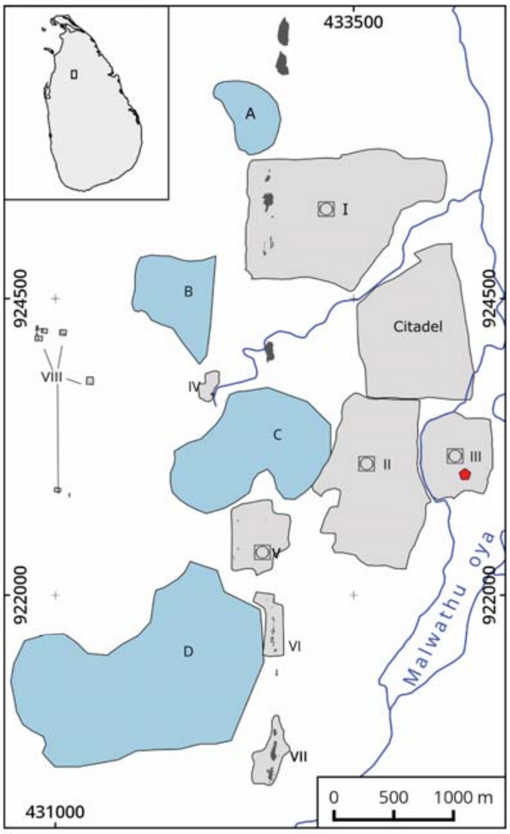
Source - Building rock
Rock type - Marble

Historical Backgrouns

The sample originated from a foundation slab in a ruined building which is located in the Jethawanarama monastery. Only a few number of architectural features in the ancient built environment were constructed using marbles. These marble features are mostly available in sacred buildings. The Jethawanarama is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.

Rock Discription

The white coloured coarse-grained marble is rich in calcite. Dolomite, forsterite and diopside are present as minor minerals. Impure minerals and dark coloured patches are present in some places.



Monasteries
I Abayagiriya
II Mahaviharaya
III Jethawanaramaya
IV Basawakkulama
V Mirisawetiya
VI Ranmasuuyana
VII Vessagiriya
VIII Western monastery

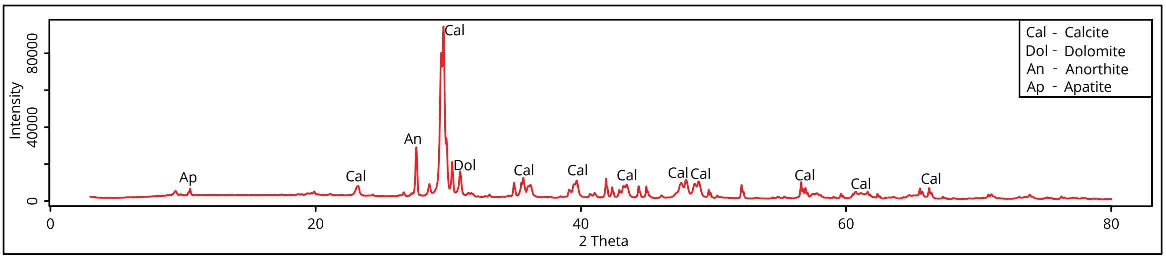
Tanks
A Perimiyankulama
B Bulankulama
C Basawakkulama
D Tisawewa
E Nuwarawewa

Sample location
Stupa
Rock outcrop

WGS84 - UTM 44 N | Wagalawatta

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	48.29	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	5.15	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.61	Rb	n.d.
MnO	n.d.	Sr	0.01
MgO	13.40	Y	n.d.
CaO	36.12	Zr	n.d.
K_2O	0.00	Nb	n.d.
P_2O_5	0.64	Ba	0.05
LOI	24.71	Ce	n.d.
Total	128.92		



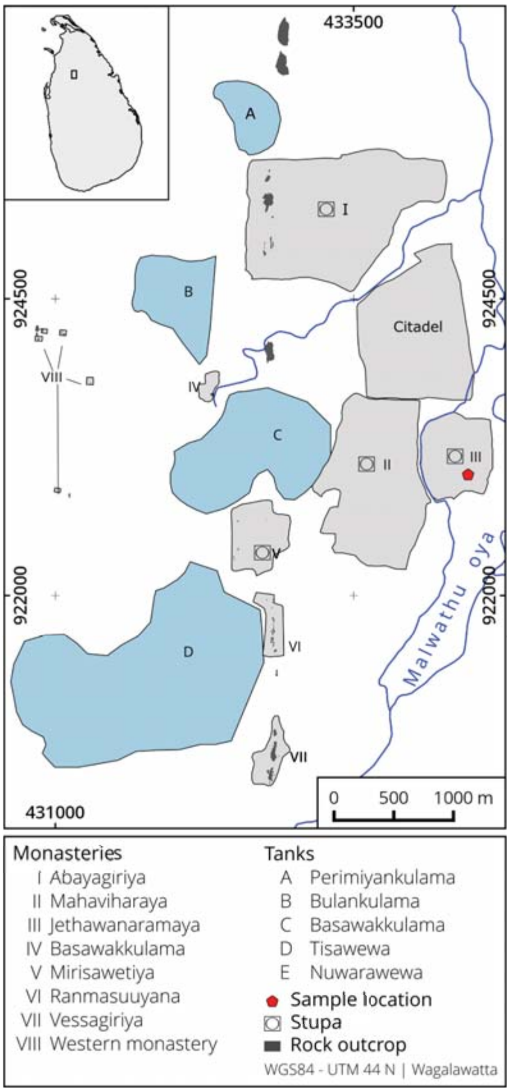
J.02.Bu. Jethawanarama Monastery

8°.20'.95" N / 80°.24'.28" E

Source - **Building rock**
Rock type - **Granitic gneiss**

Historical Background

The sample originated from a foundation slab in a rampart wall in the Jethawanarama monastery. The Jethawanarama is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.

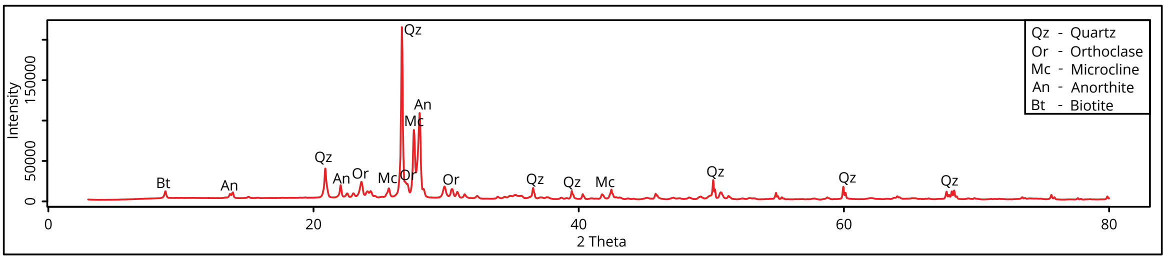


Rock Discription

Fine- to medium-grained highly weathered granitic gneiss rock show sugary texture. Major mineral constituents are quartz and orthoclase/microcline. Plagioclase (anorthite) and biotite present as accessory minerals.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	77.62	Co	0.02
TiO_2	0.14	V	0.01
Al_2O_3	12.29	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	1.62	Rb	0.02
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.19	Zr	0.01
K_2O	5.03	Nb	n.d.
P_2O_5	0.15	Ba	0.06
LOI	0.30	Ce	n.d.
Total	98.35		



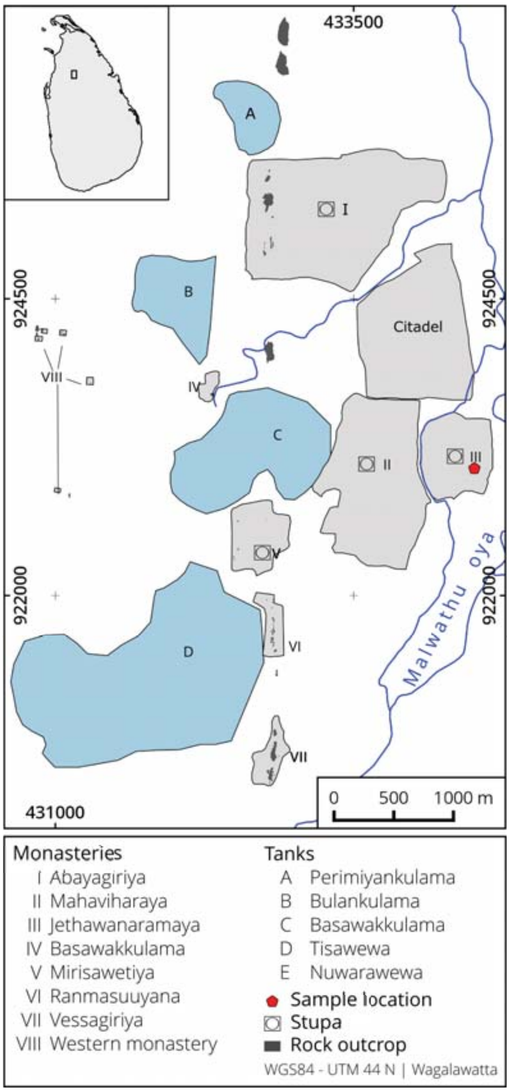
J.02.Bu. Jethawanarama Monastery

8°.21'.04" N / 80°.24'.35" E

Source - Building Rock
Rock type - Granitic gneiss

Historical Background

The sample originated from a colossal stone vessel (conventionally known as "Rice boat") in the Jethawanarama monastery. The vessel is established in a refectory hall which includes a kitchen, storage area and one open-air compartment. The Jethawanarama is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa.

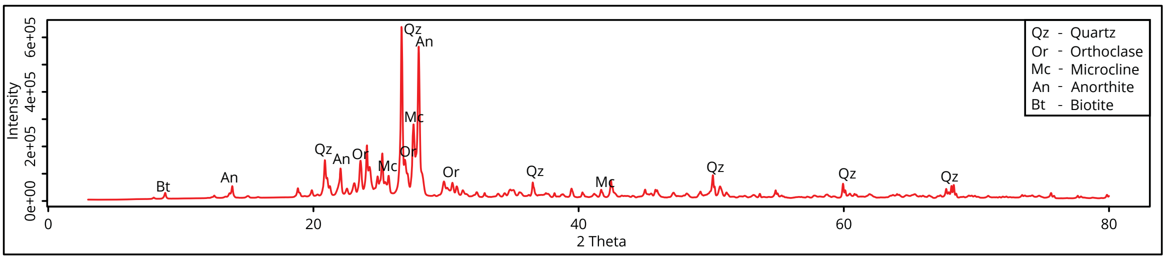


Rock Discription

The medium-grained granitiod is made up of quartz and orthoclase/microcline. Plagioclase (anorthite) and biotite mica are the minor minerals.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	72.21	Co	0.01
TiO_2	0.37	V	0.02
Al_2O_3	11.58	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	0.93	Rb	0.01
MnO	n.d.	Sr	0.14
MgO	n.d.	Y	n.d.
CaO	0.88	Zr	0.02
K_2O	5.10	Nb	n.d.
P_2O_5	0.15	Ba	0.22
LOI	0.58	Ce	n.d.
Total	91.81		



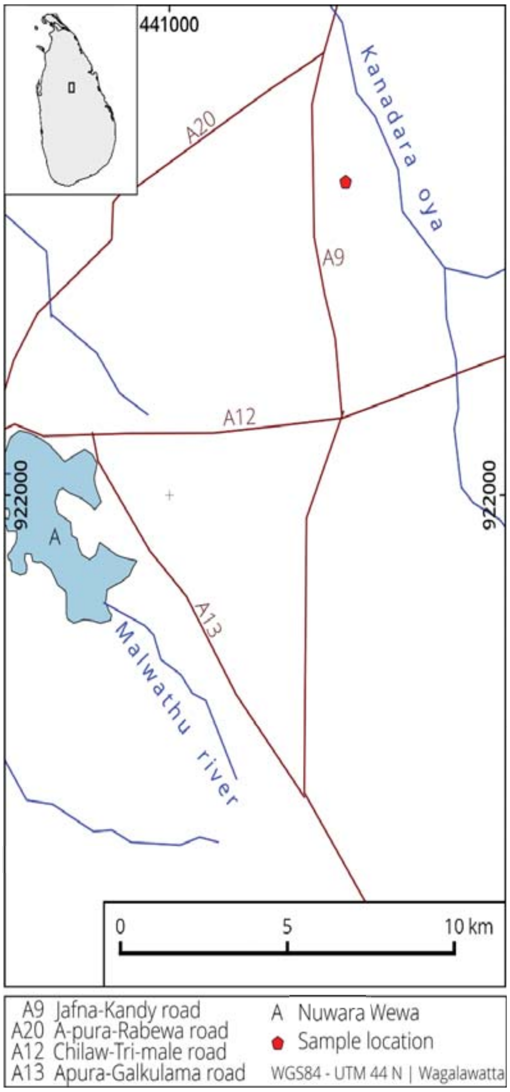
KN.01.Be.

Kanadarawa outcrop
8°.24'.33" N / 80°.30'.70" E

Source - Rock Exposure
Rock type - Marble

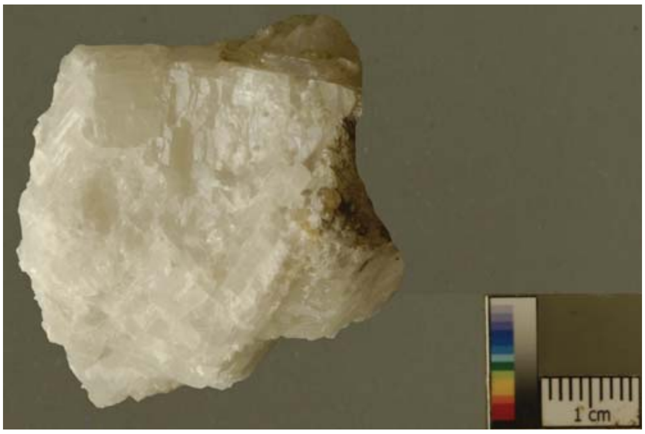
Discription of the Location

The outcrop is located in Kanadarawa (Mihinthalaya), approximately 12 km away from the historic city of Anuradhapura. Many superficial limestone outcrops are visible in the area. Natural shapes of the exposes are mostly destroyed due to modern human activities. Ancient quarry marks are not visible on the outcrops.



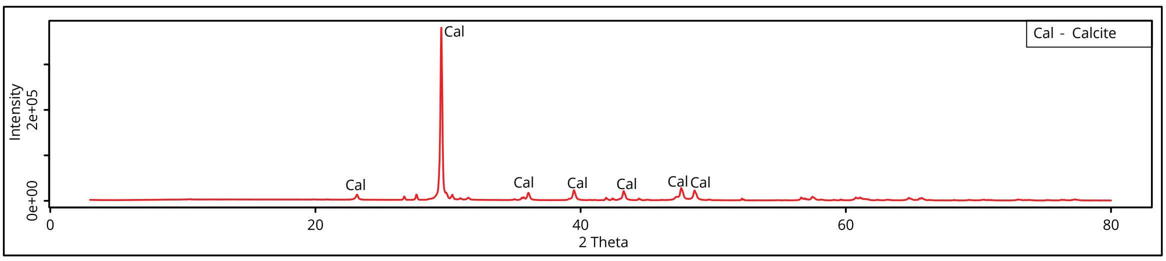
Rock Discription

The coarse grained pure white marble is made solely of calcite. These types of marbles are not common in the area.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	9.78	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	7.39	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.23	Rb	n.d.
MnO	n.d.	Sr	0.03
MgO	15.92	Y	n.d.
CaO	49.41	Zr	n.d.
K_2O	0.00	Nb	n.d.
P_2O_5	0.75	Ba	0.05
LOI	32.49	Ce	n.d.
Total	115.97		



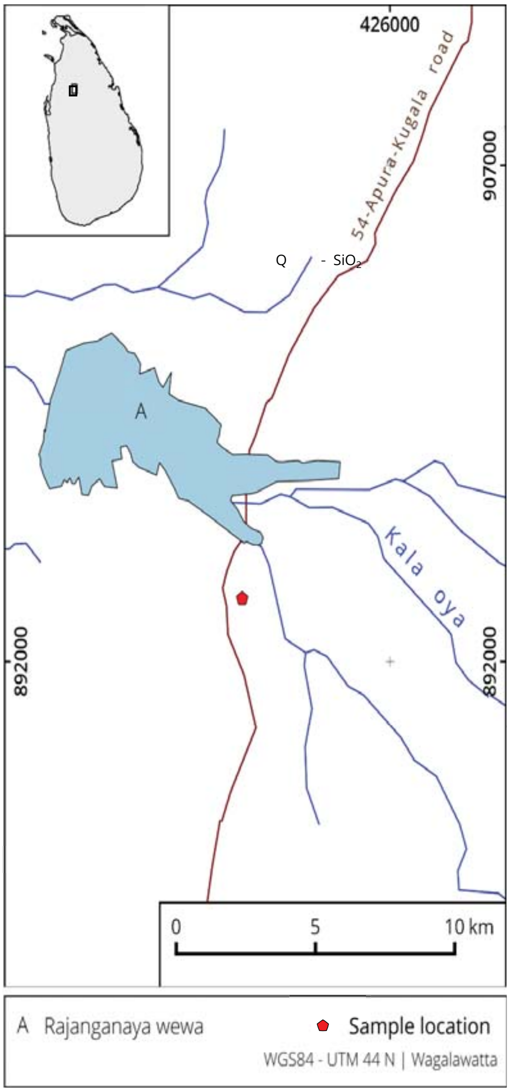
MG.04.Be.

Medagama outcrop
8°.05'.58" N / 80°.16'.57" E

Source - Rock Exposure
Rock type - Marble

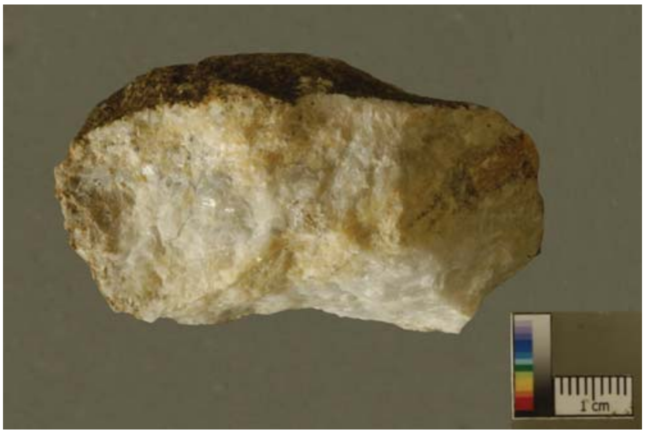
Discription of the Location

The outcrop is located in Thabuththegama village (Medagama), approximately 40 km away from the historic city of Anuradhapura. Many superficial limestone outcrops are visible in the area. Natural shapes of the exposes are mostly destroyed due to modern human activities. Ancient quarry marks are not visible on the outcrops.



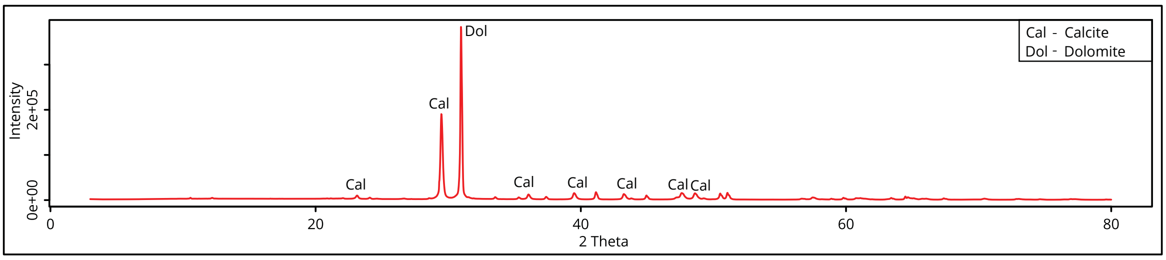
Rock discription

The white to grey colour marble is characterized by off-white coloured weathered bands containing silicate minerals. This rock is rich in medium to coarse-grained dolomite and calcite.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	6.80	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	6.78	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.24	Rb	n.d.
MnO	n.d.	Sr	0.01
MgO	17.53	Y	n.d.
CaO	42.94	Zr	n.d.
K_2O	0.00	Nb	n.d.
P_2O_5	0.62	Ba	0.04
LOI	27.57	Ce	n.d.
Total	129.37		



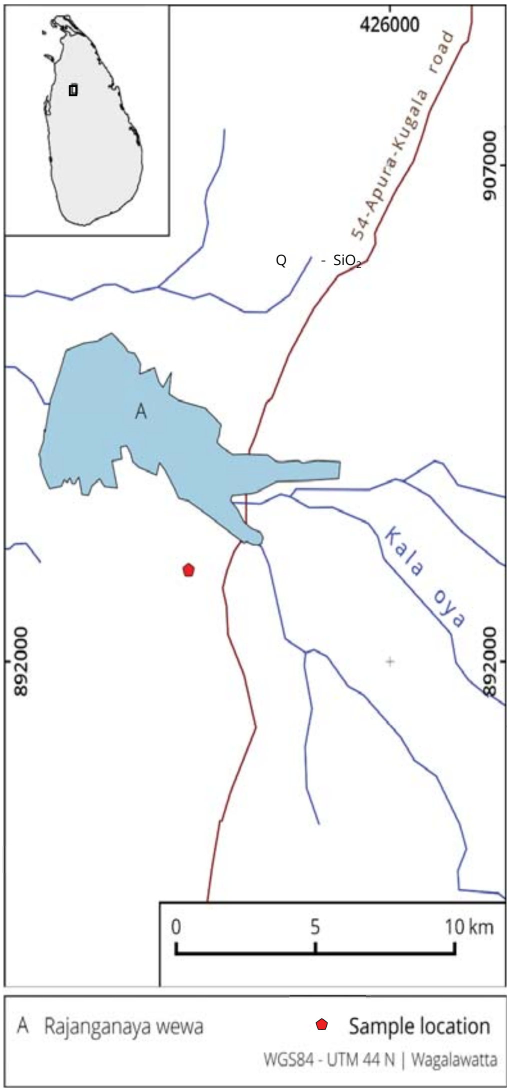
MG.06.Be.

Medagama outcrop
8°.05'.78" N / 80°.16'.31" E

Source - Rock Exposure
Rock type - Marble

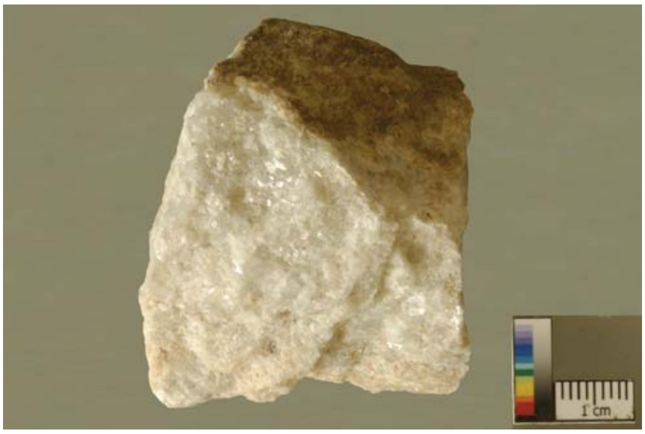
Discription of the location

The outcrop is located in Thabuththegama (Medagama), approximately 40 km away from the historic city of Anuradhapura. The area is covered by superficial limestone exposes. Natural shapes of these outcrops are mostly destroyed due to modern human activities (modern quarries/preparation of farm lands). Ancient quarry marks are not visible on the outcrops.



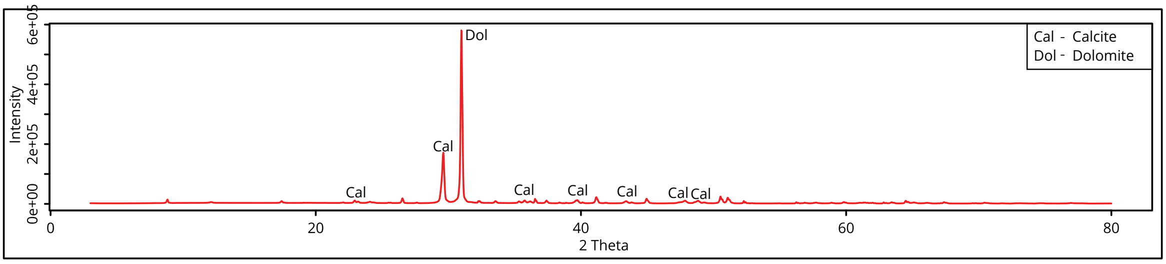
Rock Discription

Fine to medium grained off-white coloured impure marble is made up of calcite and dolomite with silicate minerals such as diopside, forsterite and mica.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	16.01	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	7.05	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.67	Rb	n.d.
MnO	n.d.	Sr	0.01
MgO	14.38	Y	n.d.
CaO	43.93	Zr	n.d.
K_2O	0.00	Nb	n.d.
P_2O_5	0.65	Ba	0.05
LOI	44.59	Ce	n.d.
Total	127.28		



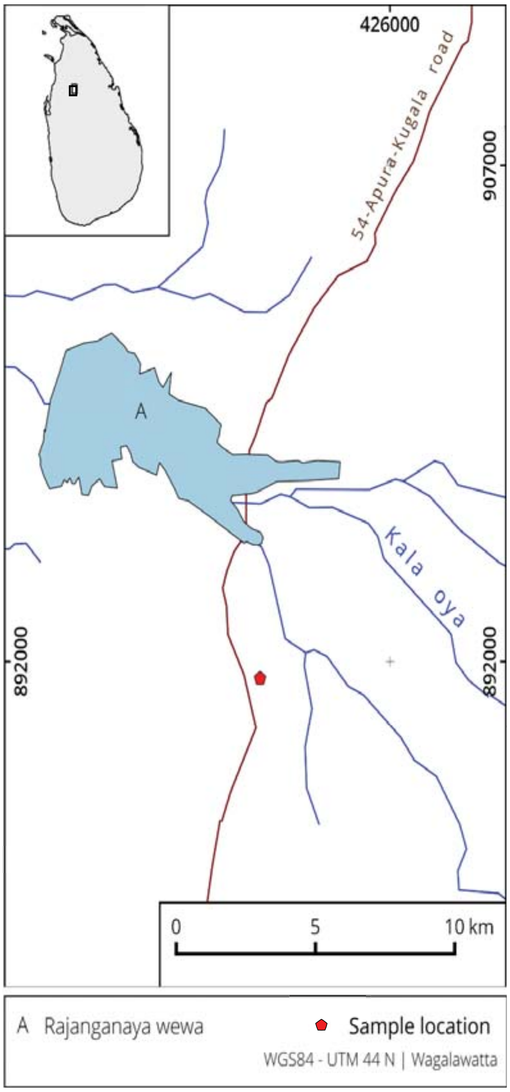
MG.11.Be.

Medagama outcrop
8°.05'.37" N / 80°.16'.59" E

Source - Rock exposure
Rock type - Marble

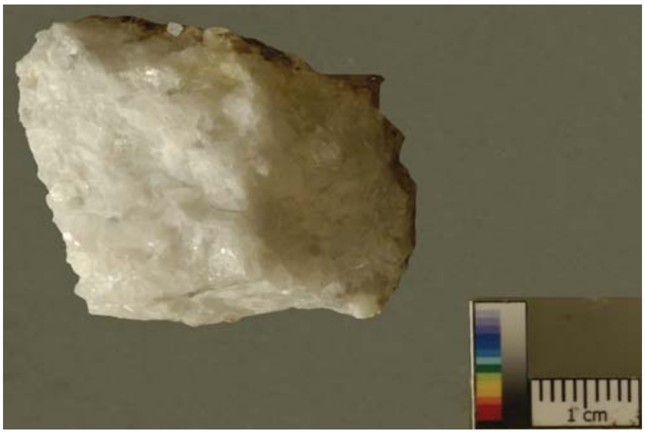
Discription of the location

The outcrop is located in Thabuththegama (Medagama), approximately 40 km away from the historic city of Anuradhapura. The area is covered by superficial limestone exposes. Natural shapes of these outcrops are mostly destroyed due to modern human activities (modern quarries/preparation of farm lands). Ancient quarry marks are not visible on the outcrops.



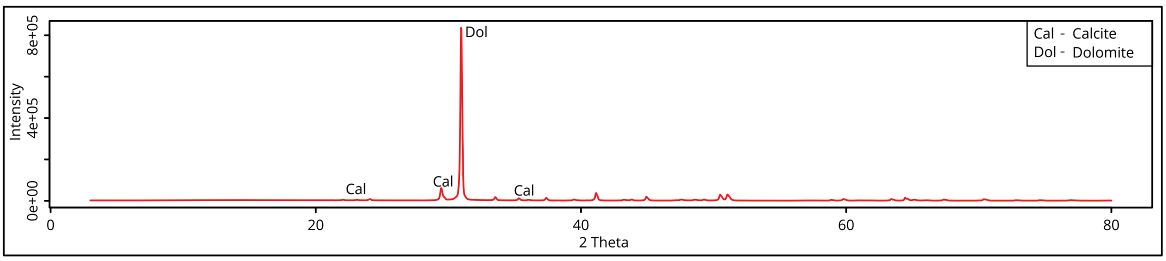
Rock Discription

The white coloured coarse-grained marble comprises of both dolomite and calcite. Minor amounts of silicate minerals such as mica and diopside are present. Apatite is the accessory mineral.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	0.00	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	4.82	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.30	Rb	n.d.
MnO	n.d.	Sr	0.01
MgO	15.60	Y	n.d.
CaO	34.51	Zr	n.d.
K_2O	0.00	Nb	n.d.
P_2O_5	0.45	Ba	0.04
LOI	46.32	Ce	n.d.
Total	102.00		



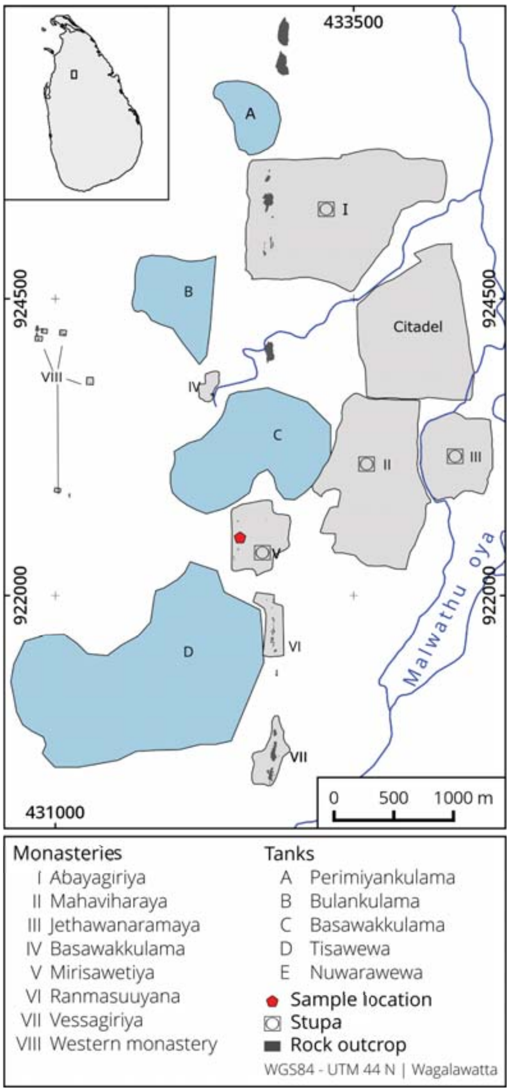
MR.01.Bu.

Mirisawetiya Monastery
8°.20'.71" N / 80°.23'.25" E

Source - Building rock
Rock type - Granitic gneiss

Historical Background

The sample originated from an internal pillar in a ruined building in the Mirisawetiya monastery. Stone pillars were used in two difierent ways in historic buildings; as internal pillars (roughly ffnished and positioned inside the brick walls) and external pillars (smoothly ffnished). The Mirisawetiya is a major monastery includes difierent types of building clusters (sacred, residential, healthcare and water management units) based on a large scale stupa.

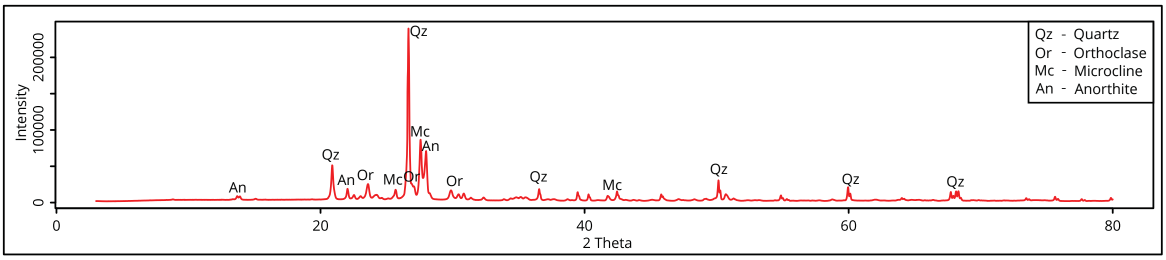


Rock Discription

The pink coloured rock is ffne- to medium-grained granitic gneiss and contains quartz, microcline and orthoclase as major minerals. Minor amounts of plagioclase (anorthite) and biotite are present.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	77.18	Co	0.01
TiO_2	0.10	V	0.00
Al_2O_3	10.01	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	1.85	Rb	0.02
MnO	n.d.	Sr	0.00
MgO	n.d.	Y	n.d.
CaO	0.72	Zr	0.00
K_2O	5.43	Nb	n.d.
P_2O_5	0.11	Ba	0.05
LOI	0.32	Ce	n.d.
Total	95.72		



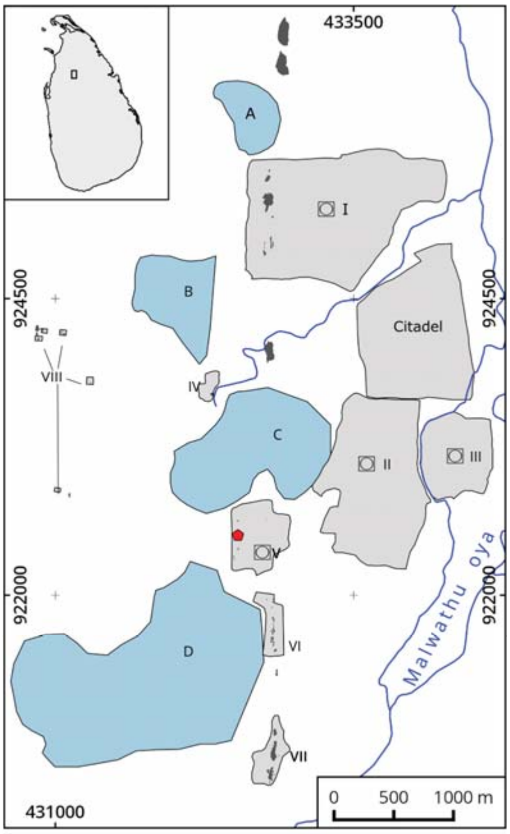
MR.03.Bu.

Mirisawetiya Monastery
8°.20'.72" N / 80°.23'.22" E

Source - Ancient quarry
Rock type - Granitic gneiss

Historical background

The site is an exposed rock boulder in the Mirisawetiya monastery. Ancient chisel marks are existing through the quarried edges of the parent rock. The Mirisawetiya is a major monastery includes difierent types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa

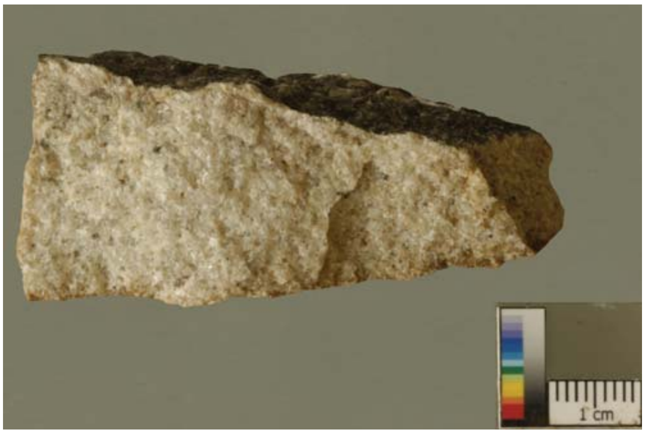


Monasteries		Tanks	
I	Abayagiriya	A	Perimiyankulama
II	Mahaviharaya	B	Bulankulama
III	Jethawanaramaya	C	Basawakkulama
IV	Basawakkulama	D	Tisawewa
V	Mirisawetiya	E	Nuwarawewa
VI	Ranmasuuyana		Sample location
VII	Vessagiriya		Stupa
VIII	Western monastery		Rock outcrop

WGS84 - UTM 44 N | Wagalawatta

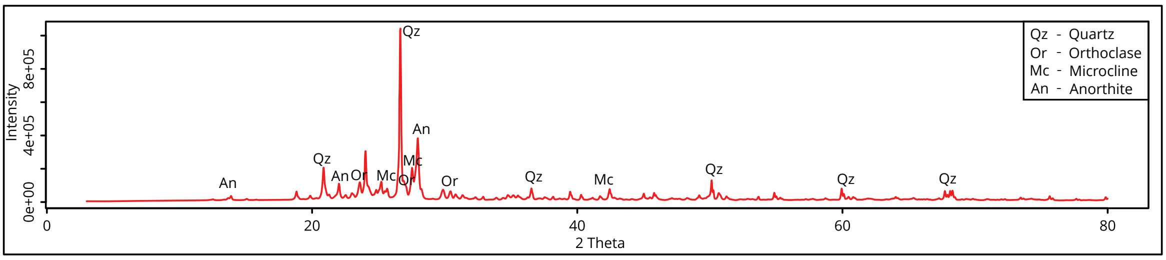
Rock Discription

The light pink coloured granitic gneiss is made up of ffne- to medium-grained quartz, and microcline with minor orthoclase and plagioclase. Due to the weathering the initial colour and the textural features of the rock may have been altered.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	74.79	Co	0.02
TiO_2	0.09	V	0.01
Al_2O_3	10.47	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	0.97	Rb	0.01
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.07	Zr	0.00
K_2O	4.19	Nb	n.d.
P_2O_5	0.07	Ba	0.11
LOI	0.39	Ce	n.d.
Total	92.03		



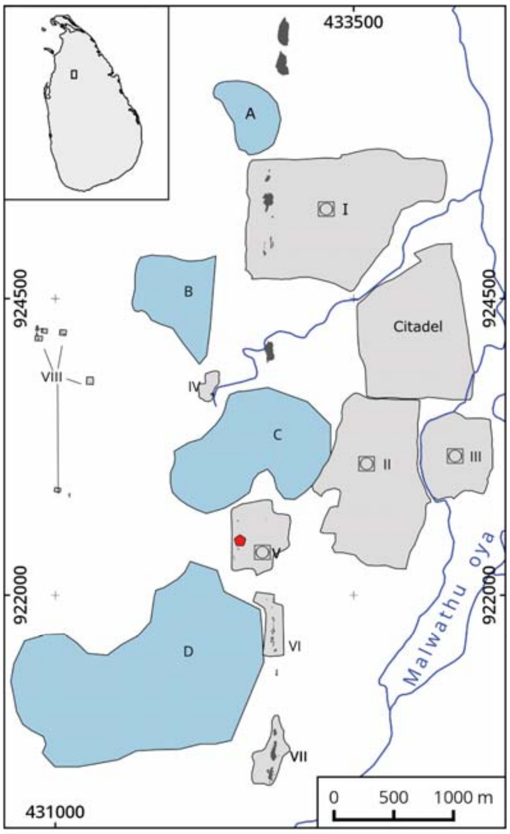
MR.04.Bu.

Mirisawetiya Monastery
8°.20'.69" N / 80°.23'.25" E

Source - Building rock
Rock type - Granitic gneiss

Historical Background

The sample originated from an internal pillar in a ruined building in the Mirisawetiya monastery. Stone pillars were used in two diﬁerent ways in historic buildings; as internal pillars (roughly ﬃnished and positioned inside the brick walls) and external pillars (smoothly ﬃnished). The Mirisawetiya is a major monastery includes diﬁerent types of building clusters (sacred, residential, healthcare and water management units) based on a large scale stupa.



Monasteries	Tanks
I Abayagiriya	A Perimiyankulama
II Mahaviharaya	B Bulankulama
III Jethawanaramaya	C Basawakkulama
IV Basawakkulama	D Tisawewa
V Mirisawetiya	E Nuwarawewa
VI Ranmasuuyana	Sample location
VII Vessagiriya	Stupa
VIII Western monastery	Rock outcrop

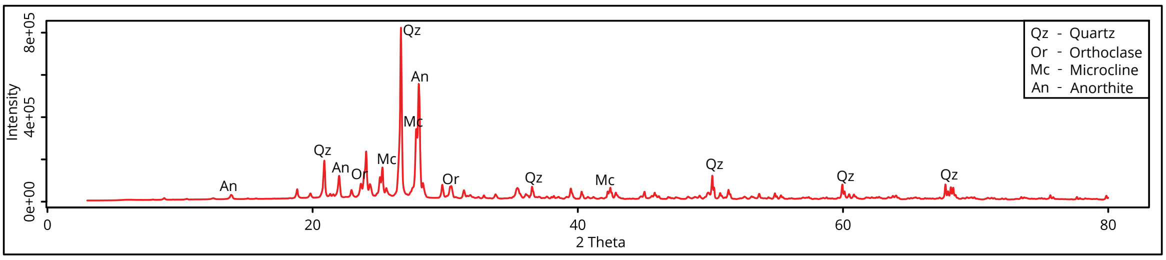
WGS84 - UTM 44 N | Wagalawatta

Rock Discription

The rock is massive to weakly foliated, pink and gray, ﬃne- to medium-grained biotite granite and the specimen is moderately weathered.

Chemical Composition (n=1)

Major elements (wt.%)		Trace elements (ppm)	
SiO_2	71.38	Co	0.02
TiO_2	0.49	V	0.01
Al_2O_3	11.84	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	7.76	Rb	0.00
MnO	n.d.	Sr	0.03
MgO	n.d.	Y	n.d.
CaO	3.57	Zr	0.02
K_2O	0.92	Nb	n.d.
P_2O_5	0.21	Ba	0.06
LOI	0.65	Ce	n.d.
Total	94.82		



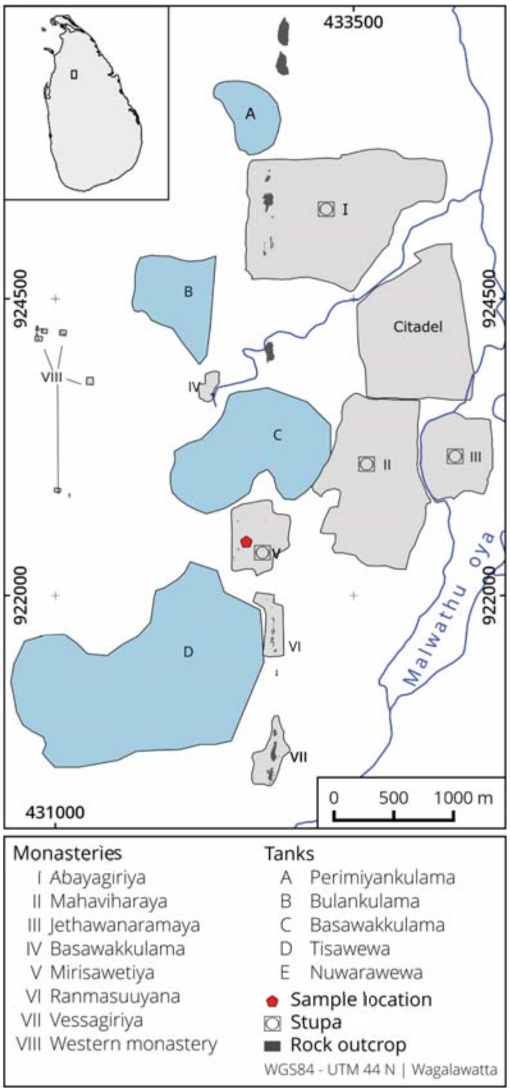
MR.05.Bu. — Mirisawetiya Monastery

8°.20'.71" N / 80°.23'.26" E

Source - Building rock
Rock type - Granitic gneiss

Historical Background

The sample originated from an internal pillar in a ruined building in the Mirisawetiya monastery. Stone pillars were used in two different ways in historic buildings; as internal pillars (roughly finished and positioned inside the brick walls) and external pillars (smoothly finished). The Mirisawetiya is a major monastery includes different types of building clusters (sacred, residential, healthcare and water management units) which are established around a large scale stupa

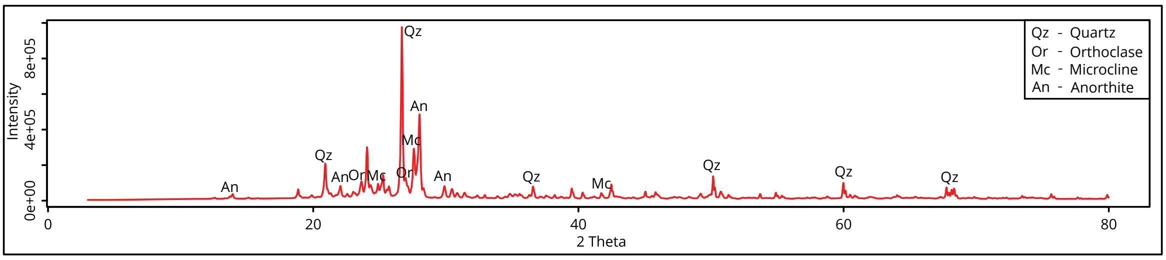


Rock Discription

The fine- to medium-grained less foliated light coloured rock consists of quartz and orthoclase as the major minerals with minor orthoclase and plagioclase. Disseminated biotite occurs as an accessory mineral.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.97	Co	0.02
TiO_2	0.38	V	0.03
Al_2O_3	9.81	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.41	Rb	0.01
MnO	n.d.	Sr	0.04
MgO	n.d.	Y	n.d.
CaO	1.23	Zr	0.04
K_2O	3.60	Nb	n.d.
P_2O_5	0.08	Ba	0.33
LOI	0.37	Ce	n.d.
Total	97.95		



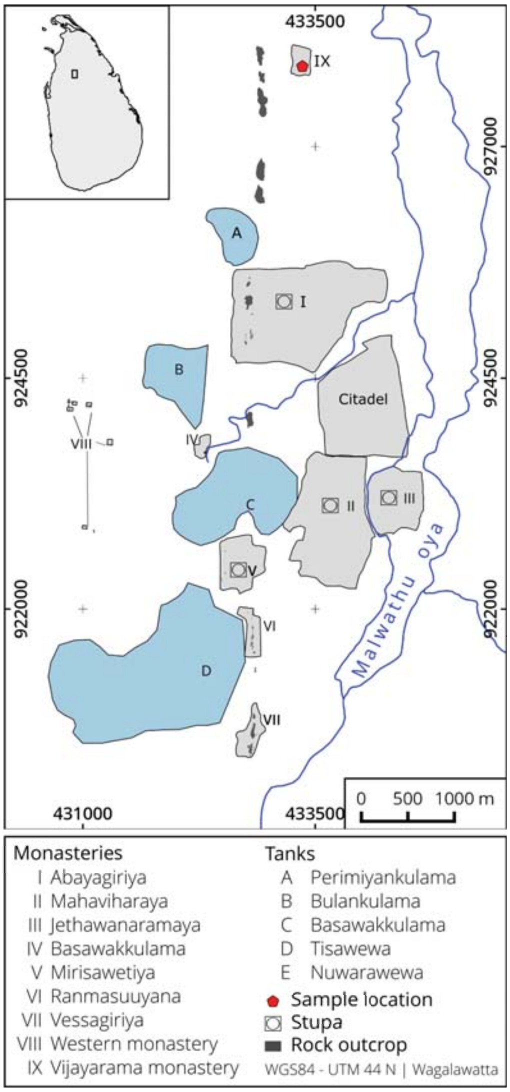
VI.01.Bu.

Vijayarama Monastery
8°.23'.91" N / 80°.23'.65" E

Source - Building rock
Rock type - Marble

Historical Background

The sample originated from a Buddha image (destroyed by treasure hunters) which is located in the Vijayarama monastery. The Vijayarama is a minor monastery includes different types of small-scale sacred, residential, healthcare and water management sectors in a small area surrounded by a rampart.

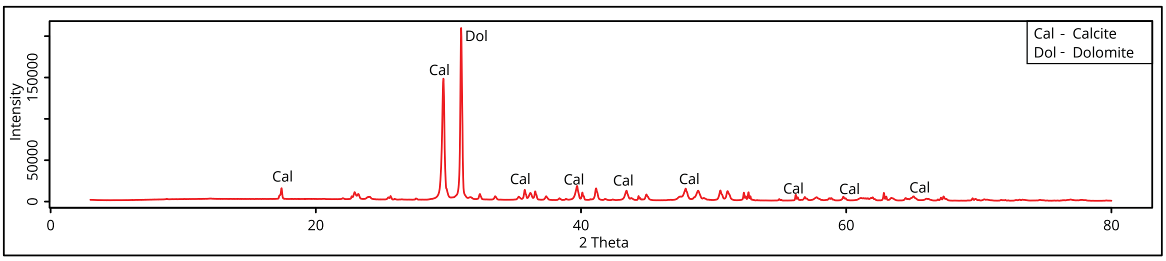


Rock Discription

The fine- to medium-grained marble is made up of dolomite and calcite. Muscovite is present as an accessory mineral.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	12.77	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	4.65	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.28	Rb	n.d.
MnO	n.d.	Sr	0.01
MgO	17.29	Y	n.d.
CaO	32.03	Zr	n.d.
K_2O	0.00	Nb	n.d.
P_2O_5	0.53	Ba	0.05
LOI	29.97	Ce	n.d.
Total	97.52		



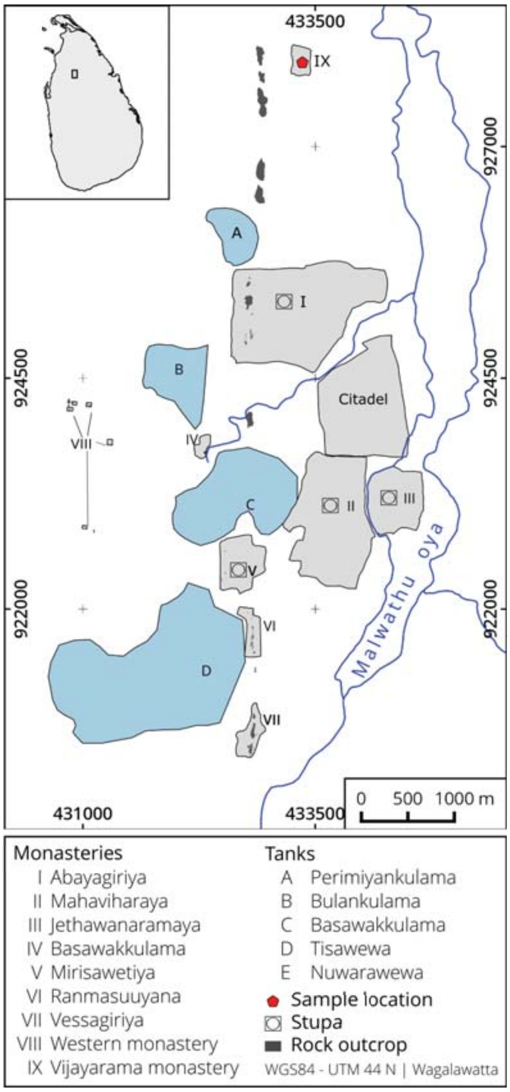
VI.02.Bu.

Vijayarama Monastery
8°.23'.64" N / 80°.23'.70" E

Source - Building rock
Rock type - Marble

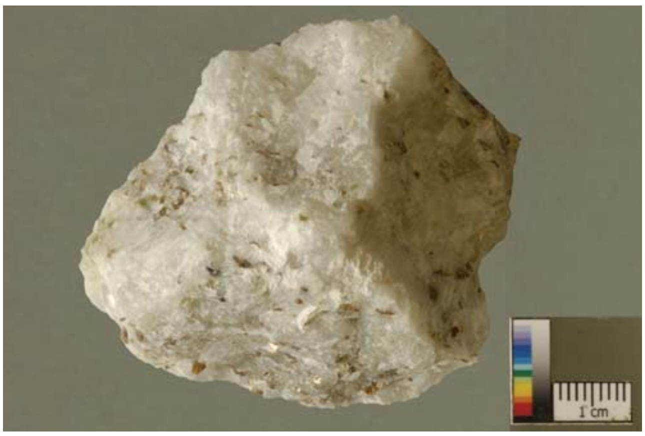
Historical Background

The sample originated from a foundation slab from the stupe which is located in the Vijayarama monastery. The Vijayarama is a minor monastery includes different types of small-scale sacred, residential, healthcare and water management sectors in a small area surrounded by a rampart.



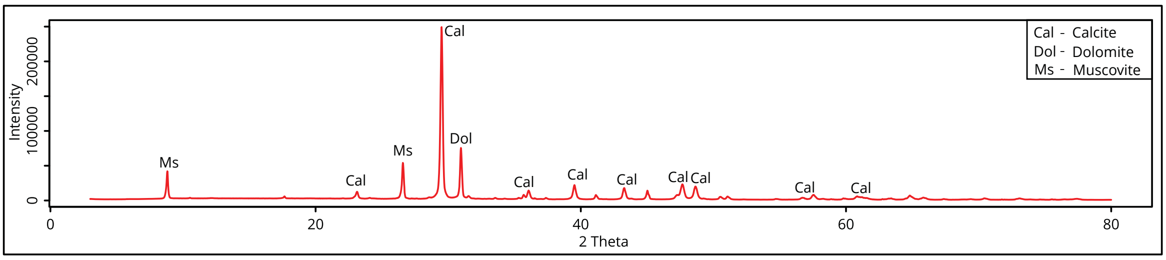
Rock Discription

The white coloured rock comprises of medium- to coarse-grained calcite and dolomite. In some zones of the rock clusters of phlogopite and olivine are present.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	8.48	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	6.91	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.61	Rb	n.d.
MnO	n.d.	Sr	0.01
MgO	16.35	Y	n.d.
CaO	44.92	Zr	n.d.
K_2O	0.78	Nb	n.d.
P_2O_5	0.65	Ba	0.51
LOI	38.04	Ce	n.d.
Total	118.09		



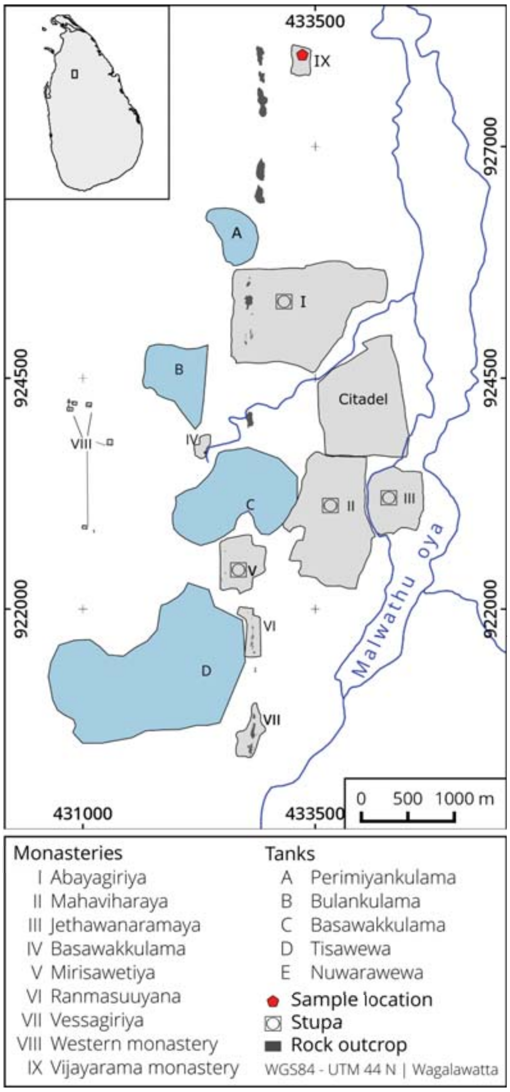
VI.02.Bu.

Vijayarama Monastery
8°.21'.04" N / 80°.24'.35" E

Source - Building rock
Rock type - Granitic gneiss

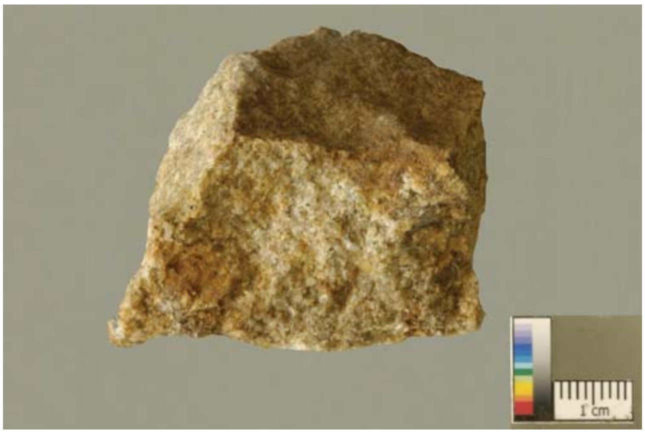
Historic Background

The sample originated from a dado decoration of an aruined building which is located the Vijayarama monastery. The Vijayarama is a minor monastery includes different types of small-scale sacred, residential, healthcare and water management sectors in a small area surrounded by a rampart.



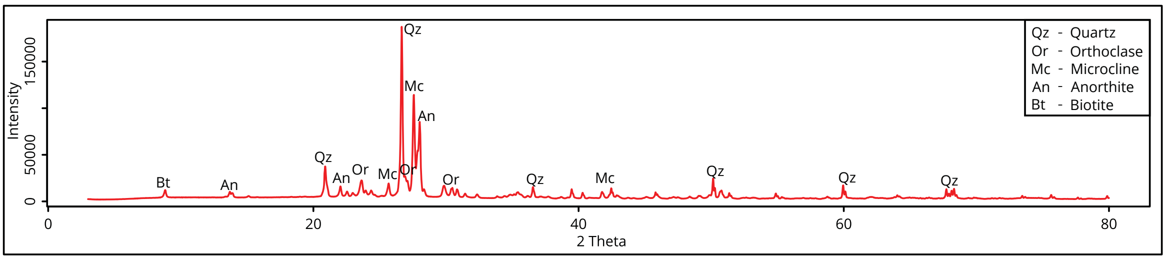
Rock Discription

The greyish-white coloured moderately weathered granitic gneiss contains typical minerals of the granite. Due to the weathering, the colour of the fresh granite has been altered. Biotite and hornblende are present as minor minerals.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.35	Co	0.01
TiO_2	0.29	V	0.01
Al_2O_3	11.66	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	3.11	Rb	0.01
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.38	Zr	0.01
K_2O	5.34	Nb	n.d.
P_2O_5	0.09	Ba	0.07
LOI	0.32	Ce	n.d.
Total	95.55		



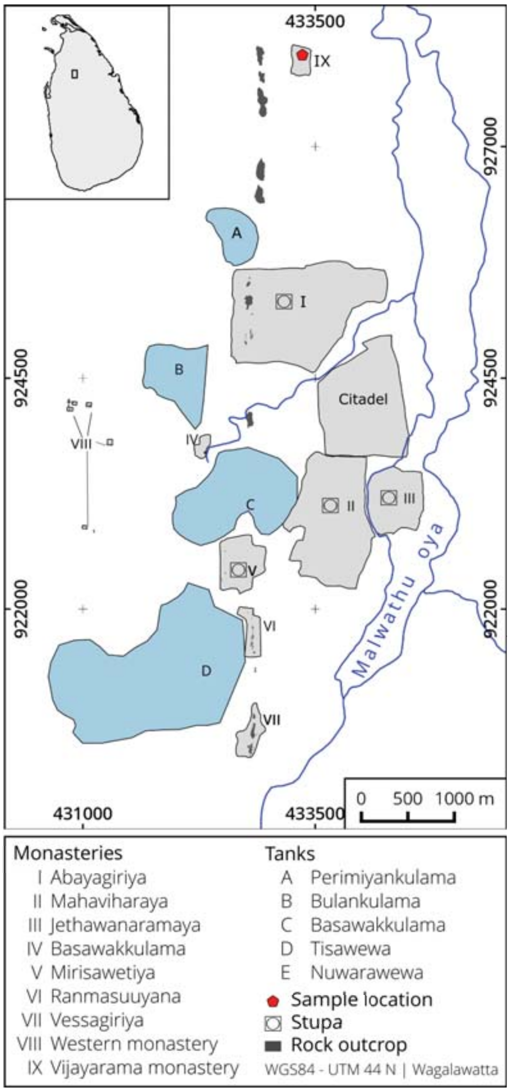
VI.04.Bu. — Vijayarama Monastery

8°.21'.04" N / 80°.24'.35" E

Source - Building rock
Rock type - Granitic gneiss

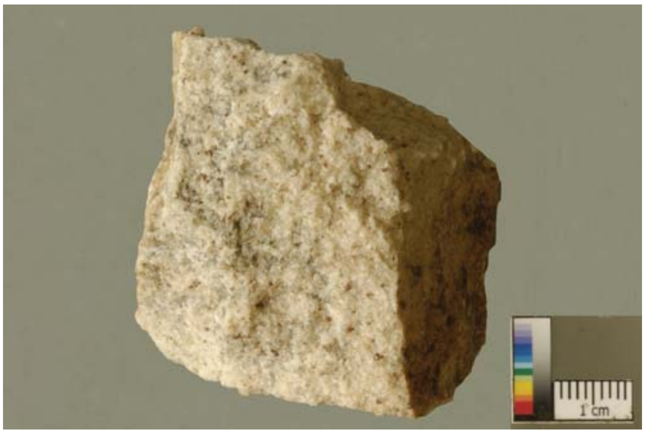
Historical Background

The sample originated from a foundation slab in a ruined building which is located in the Vijayarama monastery. The Vijayarama is a minor monastery includes different types of small-scale sacred, residential, healthcare and water management sectors in a small area surrounded by a rampart.



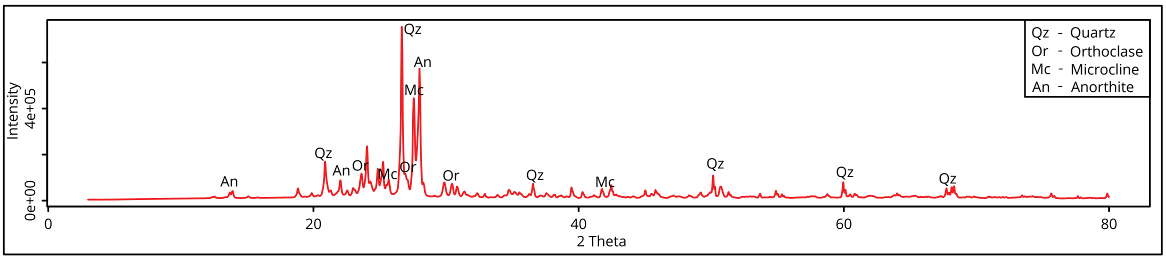
Rock Discription

The greyish-white coloured moderately weathered granitic gneiss is rich in quartz. Other major minerals are K-feldspars (microcline and orthoclase) and plagioclase. Mica is the minor mineral. The rock shows sugary texture.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.11	Co	0.01
TiO_2	0.11	V	0.01
Al_2O_3	12.07	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	0.85	Rb	0.01
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.27	Zr	0.04
K_2O	4.92	Nb	n.d.
P_2O_5	0.08	Ba	0.12
LOI	0.30	Ce	n.d.
Total	92.13		



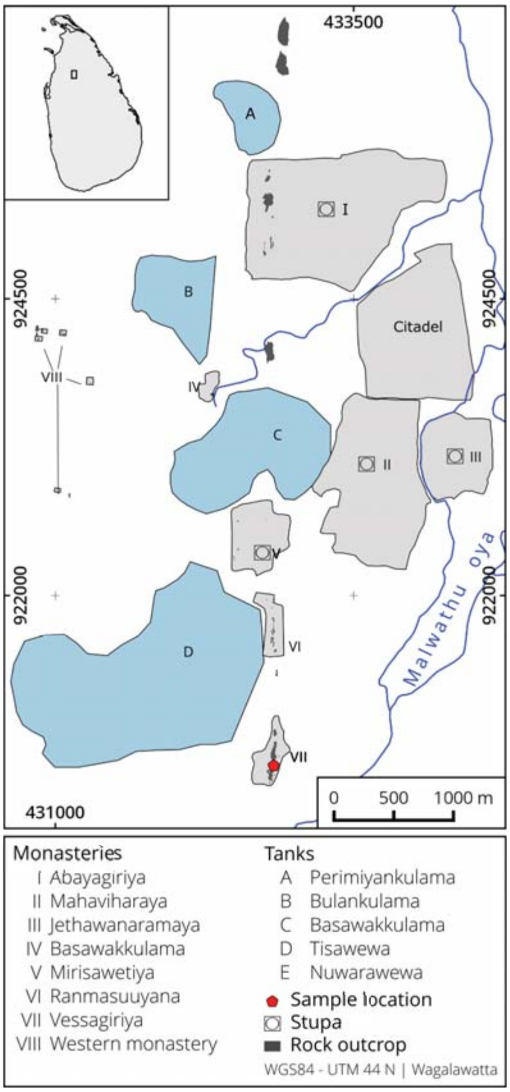
V.01.Bu.

Vessagiriya Monastery
8°.19'.65" N / 80°.23'.40" E

Source - Building rock
Rock type - Marble

Historical backgrouns

The sample originated from a balustrade in a ruined building which is located in the Vessagiriya monastery. Balustrades are vertical stone slabs decorated with mythical or human figures. They are usually standing on both sides of the staircases. The Vessagiriya is a minor monastery includes different types of small-scale sacred, residential, healthcare and water management sectors which are established based on a line of rock boulders.

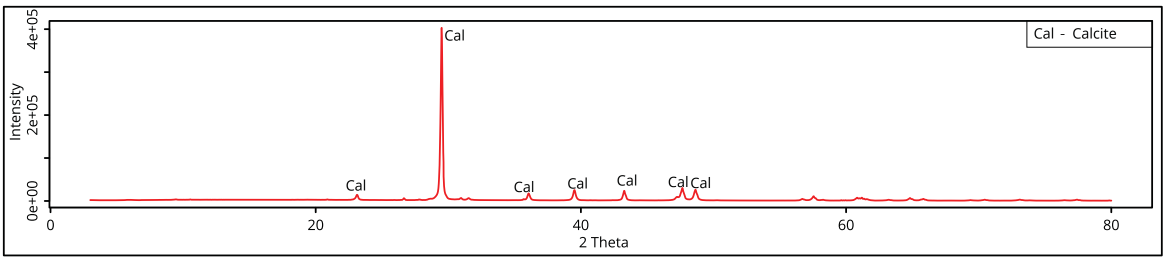


Rock Discription

The white coloured coarse-grained rock is made mainly from calcite.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	8.30	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	6.91	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.30	Rb	n.d.
MnO	n.d.	Sr	0.01
MgO	16.90	Y	n.d.
CaO	48.10	Zr	n.d.
K_2O	0.16	Nb	n.d.
P_2O_5	0.52	Ba	0.05
LOI	36.93	Ce	n.d.
Total	118.07		



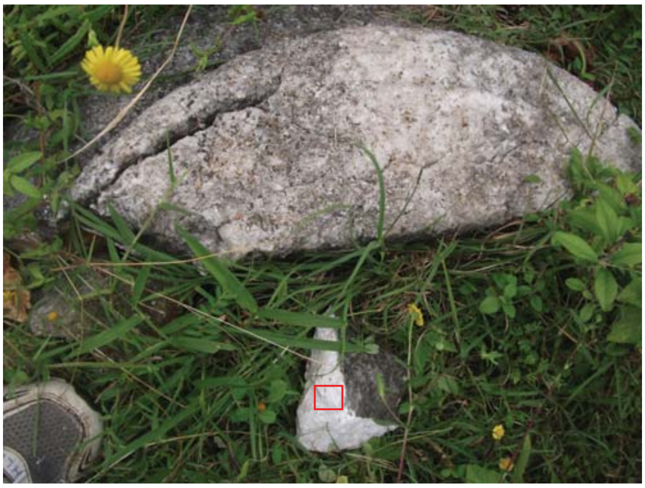
V.08.Bu.

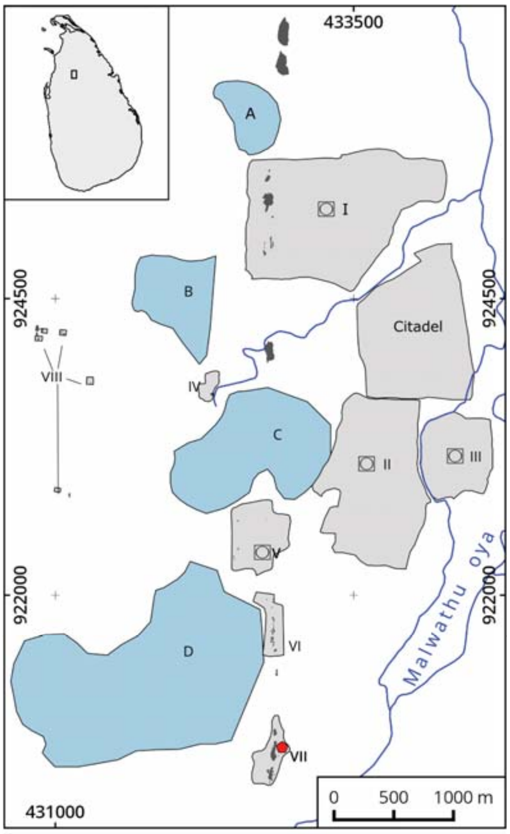
Vessagiriya Monastery
8°.19'.72" N / 80°.23'.42" E

Source - Building rock
Rock type - Marble

Historical Background

The sample originated from a Moonstone in a ruined building which is located in the Vessagiriya monastery. Moonstone is half-circled, first step of the staircase. The moonstone can be either highly decorative with animal figures and flower decorations or simple plain slab. The Vessagiriya is a minor monastery includes different types of small-scale sacred, residential, healthcare and water management sectors which are established based on a line of rock boulders.





Monasteries		Tanks	
I	Abayagiriya	A	Perimiyankulama
II	Mahaviharaya	B	Bulankulama
III	Jethawanaramaya	C	Basawakkulama
IV	Basawakkulama	D	Tisawewa
V	Mirisawetiya	E	Nuwarawewa
VI	Ranmasuuyana		Sample location
VII	Vessagiriya		Stupa
VIII	Western monastery		Rock outcrop

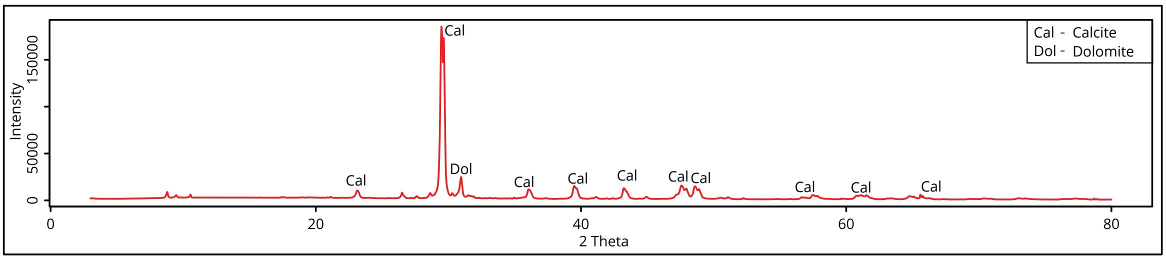
WGS84 - UTM 44 N | Wagalawatta

Rock Discription

The medium- to coarse-grained white coloured rock consists of calcite as a major mineral. Dolomite is the minor mineral.

Chemical Composition (n=1)

Major elements (wt.%)		Trace elements (ppm)	
SiO_2	8.48	Co	n.d.
TiO_2	n.d.	V	n.d.
Al_2O_3	7.23	Cu	n.d.
FeO	n.d.	Zn	n.d.
Fe_2O_3	0.29	Rb	n.d.
MnO	n.d.	Sr	0.01
MgO	16.06	Y	n.d.
CaO	48.22	Zr	n.d.
K_2O	0.15	Nb	n.d.
P_2O_5	0.69	Ba	0.04
LOI	37.94	Ce	n.d.
Total	119.07		



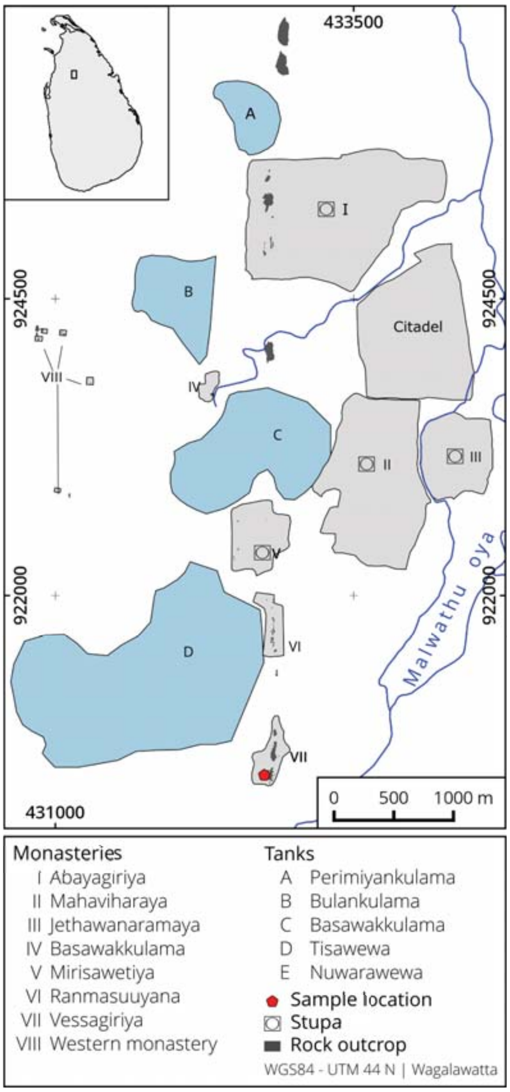
V.10.Be.

Vessagiriya Monastery
8°.19'.60" N / 80°.23'.37" E

Source - Ancient quarry
Rock type - Granitic gneiss

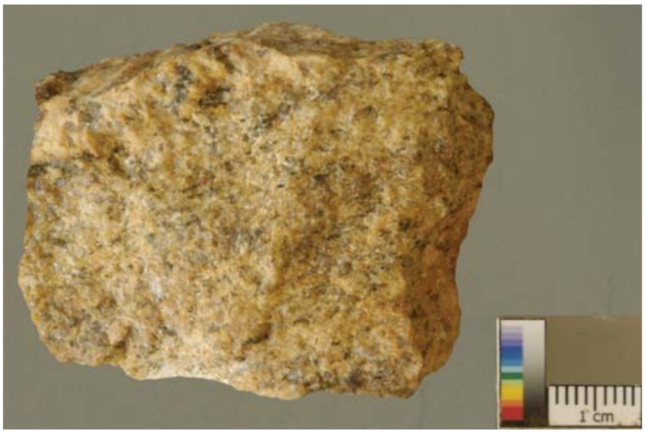
Historic Discription

The site is an exposed basement rock area located in the Vessagiriya monastery. Ancient chisel marks are existing through the quarried edges of the parent rock. The Vessagiriya is a minor monastery includes different types of small-scale sacred, residential, healthcare and water management sectors which are established based on a line of rock boulders.



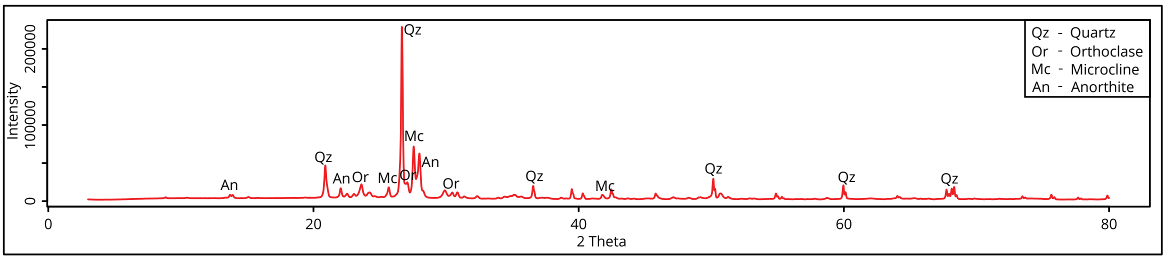
Rock Discription

The fine- to medium-grained rock contains quartz and K-feldspar as major minerals with minor plagioclase (anorthite). Biotite and hornblende rich layers are also present in the rock. The rock surface has been strongly



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	78.96	Co	0.02
TiO_2	0.16	V	0.00
Al_2O_3	10.17	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.45	Rb	0.02
MnO	n.d.	Sr	0.00
MgO	n.d.	Y	n.d.
CaO	0.72	Zr	0.02
K_2O	5.41	Nb	n.d.
P_2O_5	0.08	Ba	0.05
LOI	0.35	Ce	n.d.
Total	97.29		



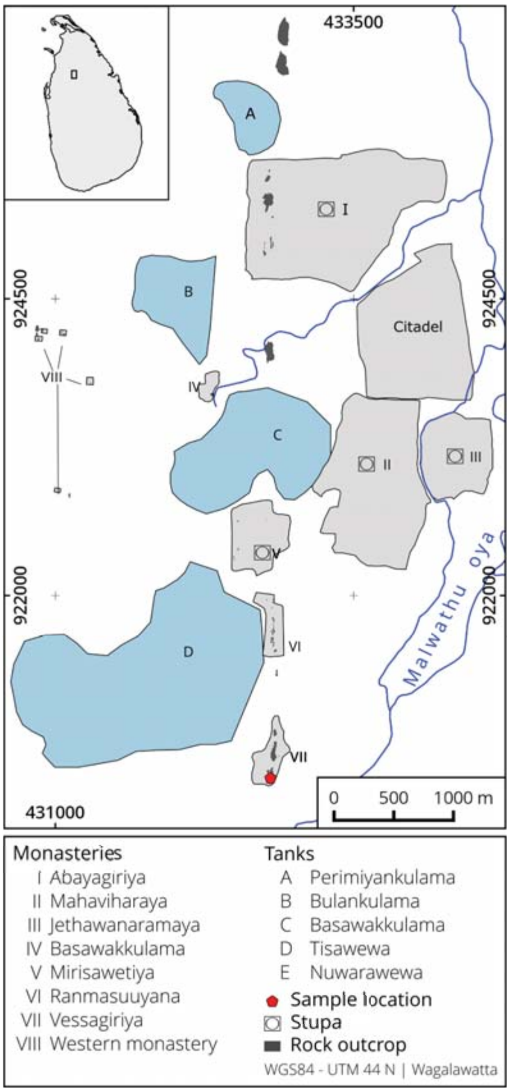
V.16.Be. Vessagiriya Monastery

8°.19'.59" N / 80°.23'.38" E

Source - Ancient quarry
Rock type - Granitic gneiss

Historical Background

The site is an exposed rock boulder located in the Vessagiriya monastery. Ancient chisel marks are existing through the quarried edges of the parent rock. The Vessagiriya is a minor monastery includes different types of small-scale sacred, residential, healthcare and water management sectors which are established based on a line of rock boulders.

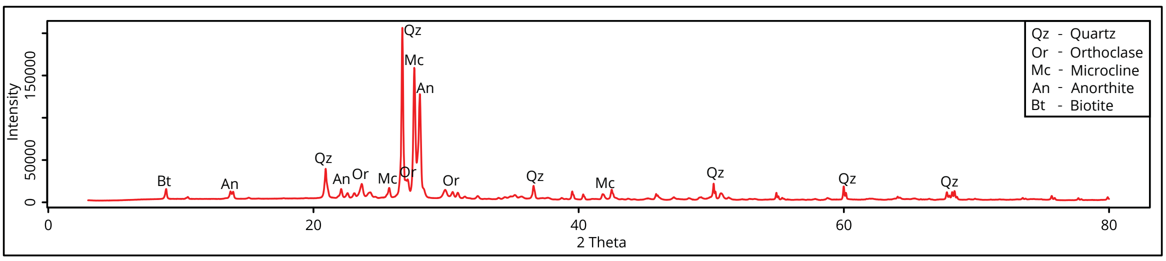


Rock Discription

This is fa ine to medium-grained rock. Quartz and K-feldspar (microcline) are the major minerals. Plagioclase (anorthite) and alterd biotite are present as minor mineral constituents.

Chemical Composition (n=1)

Major elements (wt.%)		Trace elements (ppm)	
SiO_2	74.91	Co	0.01
TiO_2	0.18	V	0.00
Al_2O_3	11.16	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	2.61	Rb	0.02
MnO	n.d.	Sr	0.00
MgO	n.d.	Y	n.d.
CaO	0.81	Zr	0.02
K_2O	5.49	Nb	n.d.
P_2O_5	0.11	Ba	0.06
LOI	0.63	Ce	n.d.
Total	96.91		



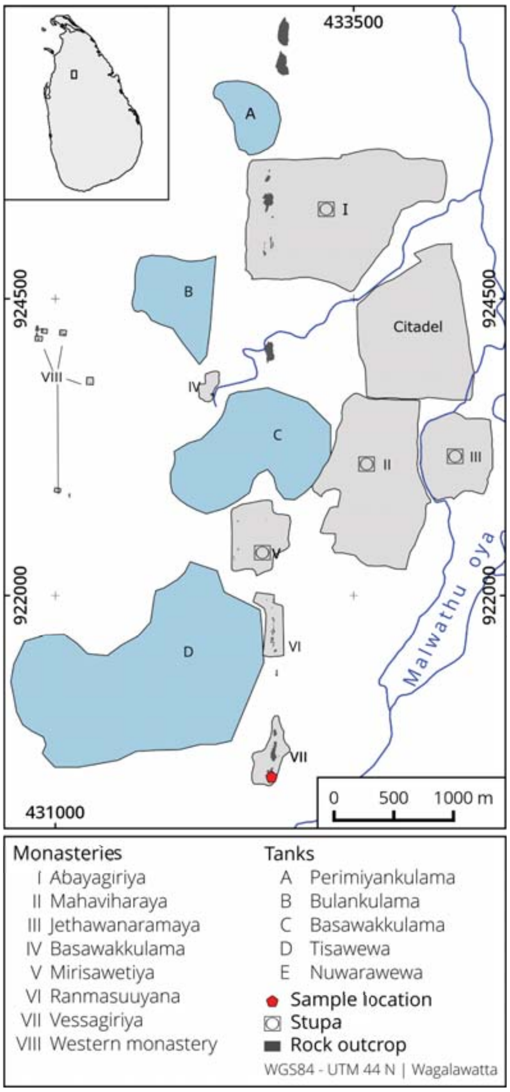
V.19.Be. Vessagiriya Monastery

8°.19'.59" N / 80°.23'.39" E

Source - Ancient quarry
Rock type - Granitic gneiss

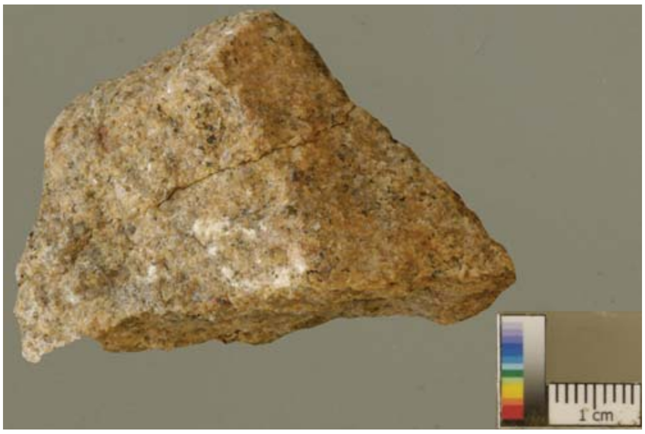
Historical Background

The site is an exposed rock boulder located in the Vessagiriya monastery. Ancient chisel marks are existing through the quarried edges of the parent rock. The Vessagiriya is a minor monastery includes different types of small-scale sacred, residential, healthcare and water management sectors which are established based on a line of rock boulders.



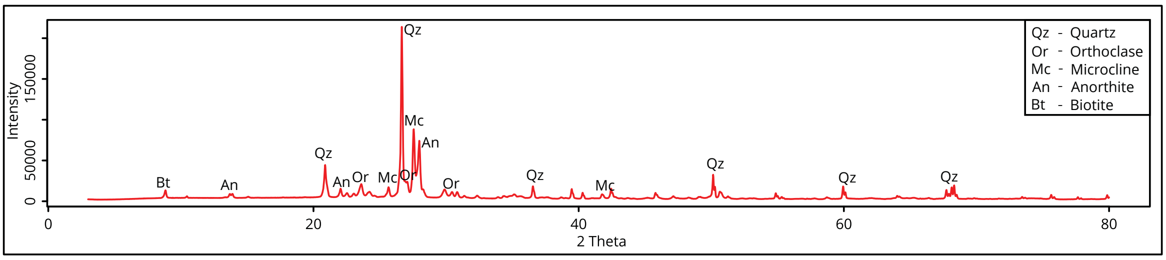
Rock Discription

The fine- to medium-grained brownish pink coloured rock contain quartz and K-feldspar (orthoclase and microcline) as major minerals with minor plagioclase (albite) and biotite.



Chemical Composition (n=1)

Major elements (wt.%)		Trace elements (ppm)	
SiO_2	76.40	Co	0.02
TiO_2	0.23	V	0.01
Al_2O_3	11.24	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	2.17	Rb	0.03
MnO	n.d.	Sr	0.00
MgO	n.d.	Y	n.d.
CaO	0.80	Zr	0.02
K_2O	5.60	Nb	n.d.
P_2O_5	0.14	Ba	0.05
LOI	0.55	Ce	n.d.
Total	97.14		



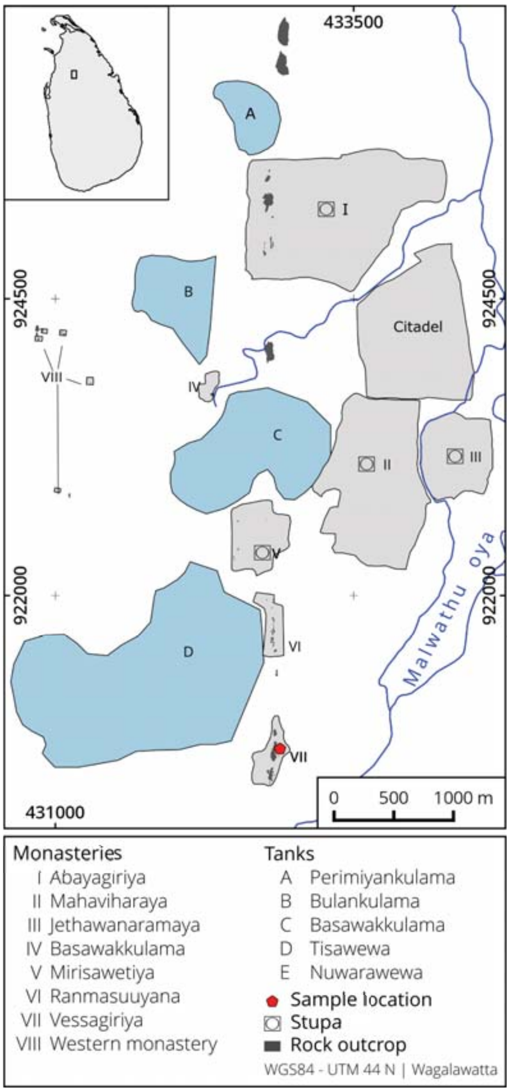
V.25.Be.

Vessagiriya Monastery
8°.19'.71" N / 80°.23'.42" E

Source - Ancient quarry
Rock type - Granitic gneiss

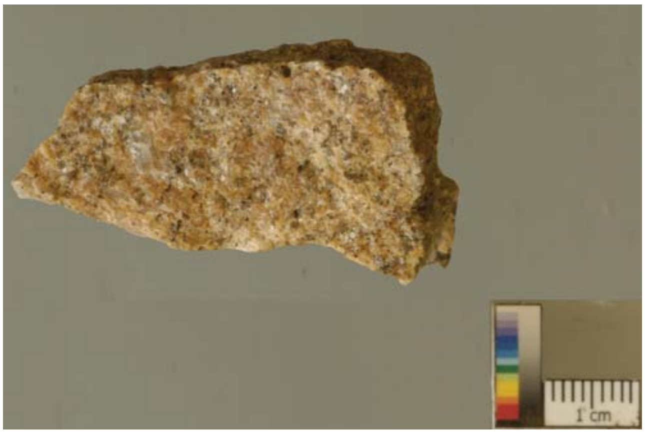
Historical Background

The site is an exposed rock boulder located in the Vessagiriya monastery. Ancient chisel marks are existing through the quarried edges of the parent rock. Moreover, a relinquished line of drilled quarry holes is also visible on the surface. The Vessagiriya is a minor monastery includes different types of small-scale sacred, residential, healthcare and water management sectors which are established based on a line of rock boulders.



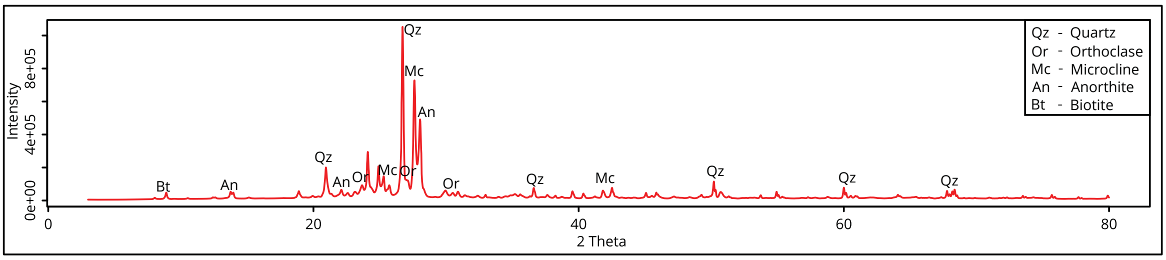
Rock Discription

The fine- to medium-grained rock contains typical minerals of granitic gneiss in the area (quartz and K-feldspar – major, plagioclase (anorthite) and biotite – minor).



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	76.51	Co	0.01
TiO_2	0.21	V	0.01
Al_2O_3	11.28	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	2.34	Rb	0.02
MnO	n.d.	Sr	0.00
MgO	n.d.	Y	n.d.
CaO	0.77	Zr	0.02
K_2O	5.73	Nb	n.d.
P_2O_5	0.12	Ba	0.09
LOI	0.64	Ce	n.d.
Total	97.60		



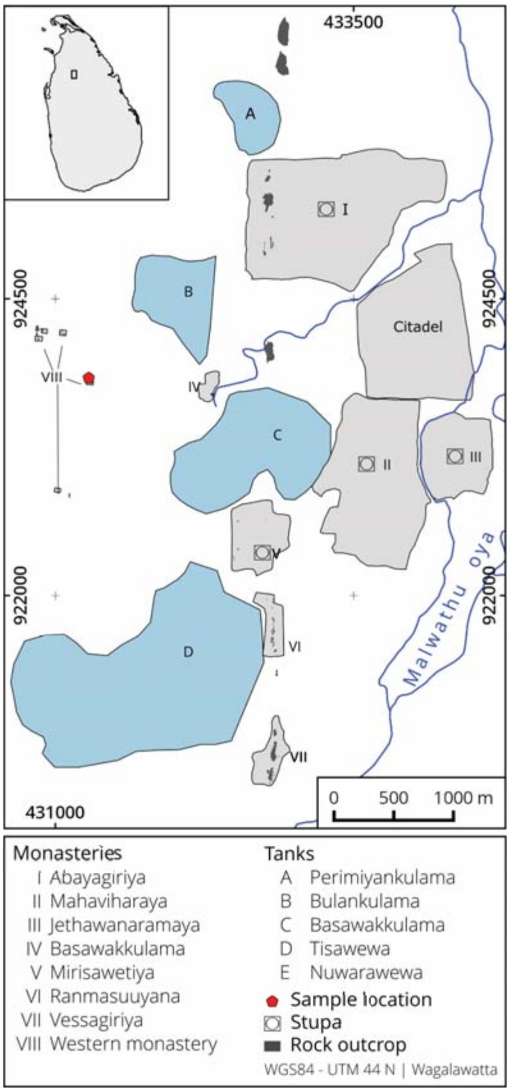
WM.03.Bu.

Western Monastery
8°.21'.43" N / 80°.22'.56" E

Source - Building rock
Rock type - Granitic gneiss

Historical Background

The sample originated from a slab which was used for dado decoration of a ruined building which is located in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.

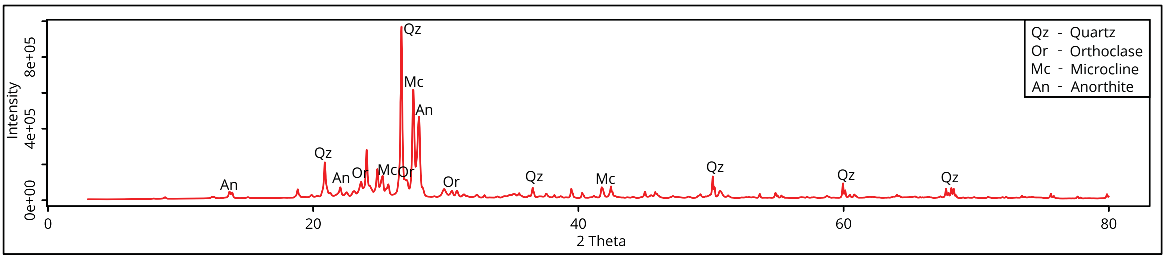


Rock Discription

The fine- to medium-grained rock consists of quartz, microcline and orthoclase as major minerals. Plagioclase, biotite mica and hornblende are minor minerals.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	74.59	Co	0.01
TiO_2	0.14	V	0.01
Al_2O_3	10.92	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.81	Rb	0.02
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	0.75	Zr	0.02
K_2O	5.71	Nb	n.d.
P_2O_5	0.05	Ba	0.07
LOI	0.50	Ce	n.d.
Total	94.49		



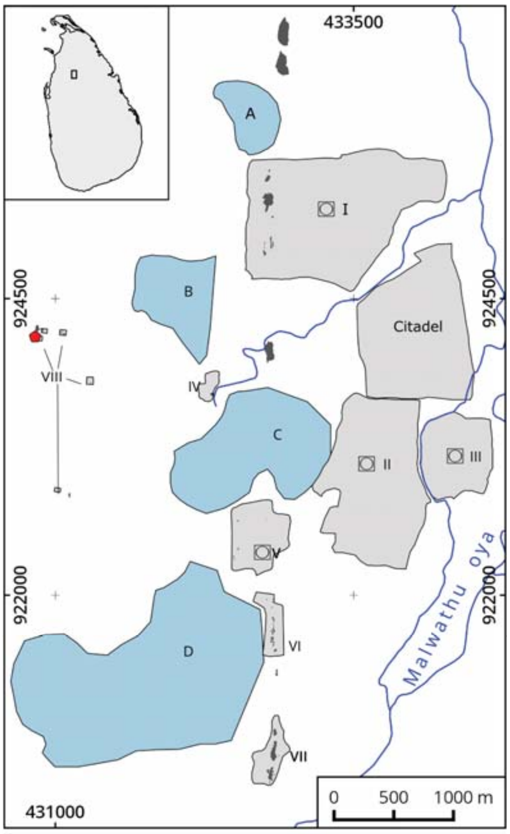
WM.04.Bu.

Western Monastery
8°.21'.60" N / 80°.22'.33" E

Source - Building rock
Rock type - Granitic gneiss

Historical Background

The sample originated from a slab which was used in a wall of a ruined building which is located in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.



Monasteries		Tanks	
I	Abayagiriya	A	Perimiyankulama
II	Mahaviharaya	B	Bulankulama
III	Jethawanaramaya	C	Basawakkulama
IV	Basawakkulama	D	Tisawewa
V	Mirisawetiya	E	Nuwarawewa
VI	Ranmasuuyana		Sample location
VII	Vessagiriya		Stupa
VIII	Western monastery		Rock outcrop

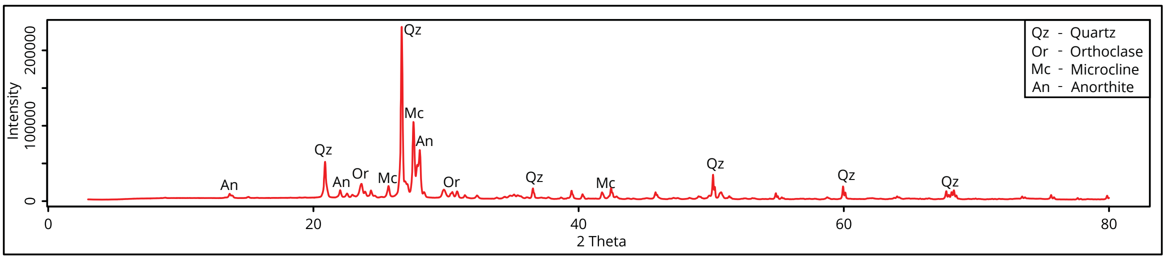
WGS84 - UTM 44 N | Wagalawatta

Rock Discription

The poorly foliated rock is mostly composed of quartz with pink coloured orthoclase and microcline. Plagoclase and biotite mica are present as minor minerals.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.85	Co	0.01
TiO_2	0.21	V	0.01
Al_2O_3	10.38	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.82	Rb	0.01
MnO	n.d.	Sr	0.02
MgO	n.d.	Y	n.d.
CaO	1.34	Zr	0.02
K_2O	5.28	Nb	n.d.
P_2O_5	0.07	Ba	0.10
LOI	0.45	Ce	n.d.
Total	97.79		



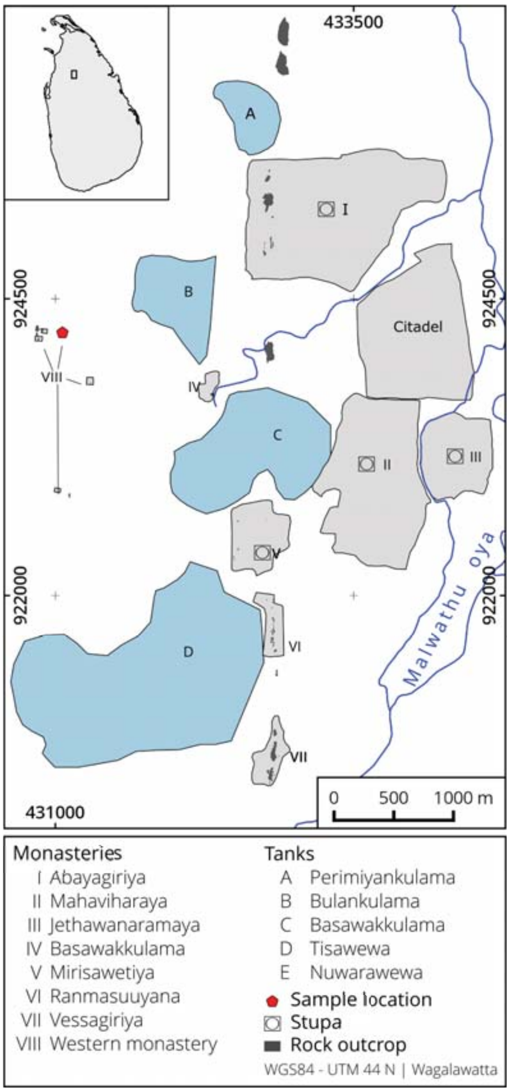
WM.07.Bu.

Western Monastery
Rockt ypeGr a Rnockkyi gGs

D15'4l - N5°E°60'14/
S14/ 2uBl - d'36°24d6l°..

8°. 21'°43"N34/0'156E

The sample originated from a slab which was used in a wall of a ruined building which is located in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.

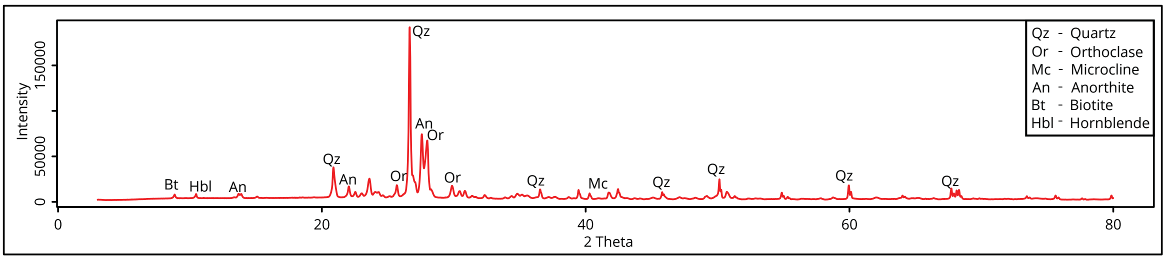


S14/ H°. 4' °B2°16

The medium- to coarse-grained granitic gneiss with biotite and hornblende rich layers. Quartz is the major mineral with subordinate amounts of orthoclase and plagioclase. Variable amounts of hornblende and biotite mica are present. Pegmatite patches are also present in the rock.

Chl m°43"C1mB1. °2°16 (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	76.08	Co	0.01
TiO_2	0.30	V	0.01
Al_2O_3	10.39	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.83	Rb	0.01
MnO	n.d.	Sr	0.02
MgO	n.d.	Y	n.d.
CaO	1.31	Zr	0.02
K_2O	5.27	Nb	n.d.
P_2O_5	0.15	Ba	0.06
LOI	0.49	Ce	n.d.
Total	94.45		



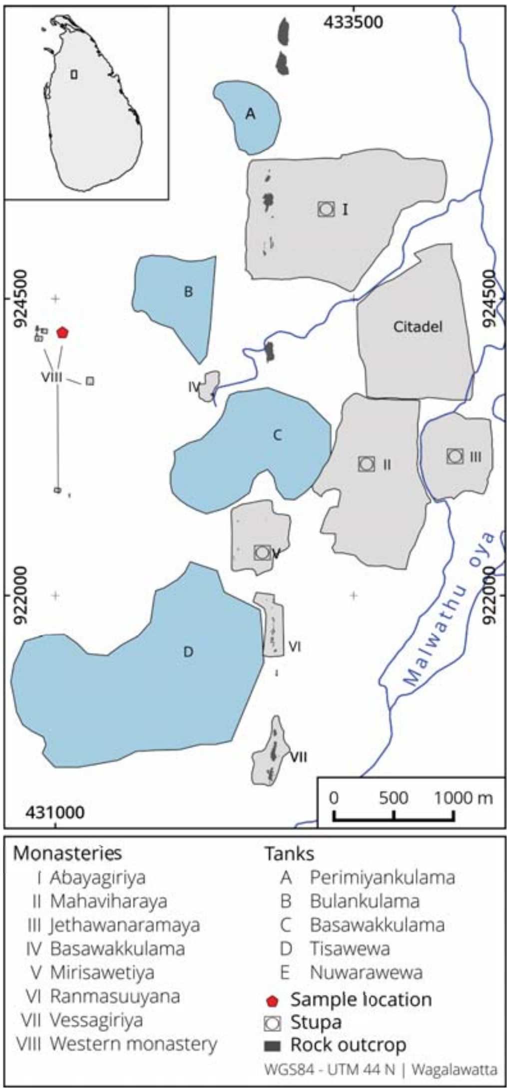
WM.08.Bu.

Western Monastery
8°.21'.43" N / 80°.22'.56" E

Source - Building rock
Rock type - Granitic gneiss

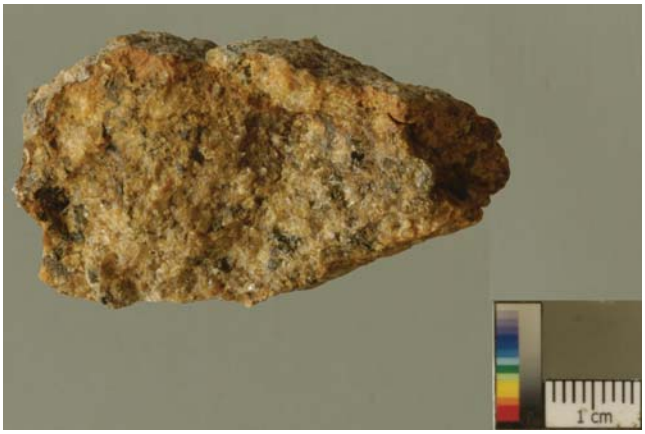
Historical Backgrouns

The sample originated from a slab which was used in a rampart in the Western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.



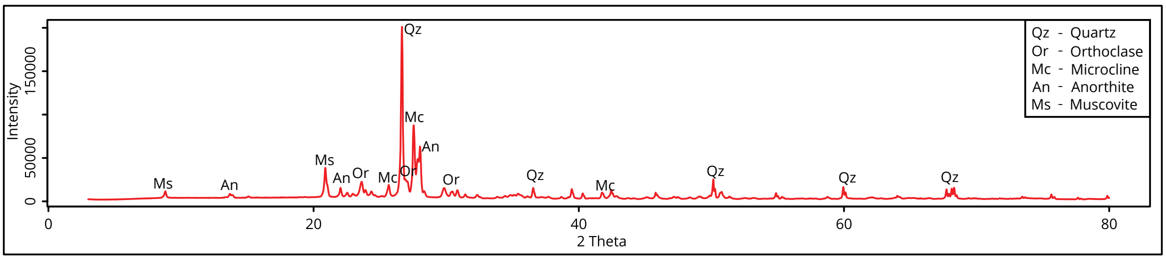
Rock Discription

The medium- to coarse-grained moderately weathered granitic gneiss is made up of quartz and orthoclase with minor plagioclase and hornblende. Muscovite occurs as a weathering product.



Chemical Composition (n=1)

Major elements (wt.%)		Trace elements (ppm)	
SiO_2	74.08	Co	0.02
TiO_2	0.34	V	0.01
Al_2O_3	11.04	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	2.08	Rb	0.02
MnO	n.d.	Sr	0.02
MgO	n.d.	Y	n.d.
CaO	1.29	Zr	0.03
K_2O	5.54	Nb	n.d.
P_2O_5	0.13	Ba	0.09
LOI	0.44	Ce	n.d.
Total	95.14		



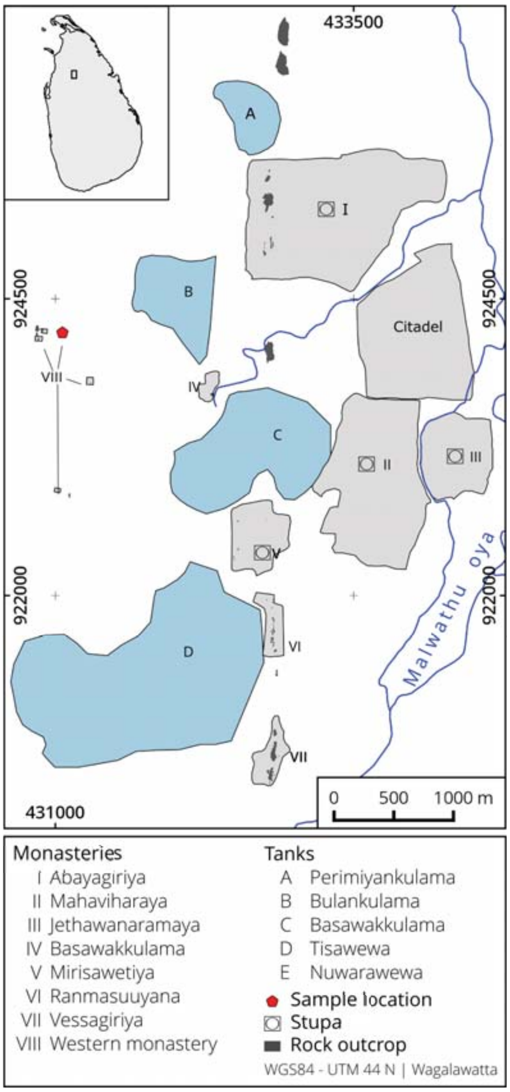
WM.09.Bu.

Western Monastery
8°.21'.43" N / 80°.22'.56" E

Source - Building rock
Rock type - Granitic gneiss

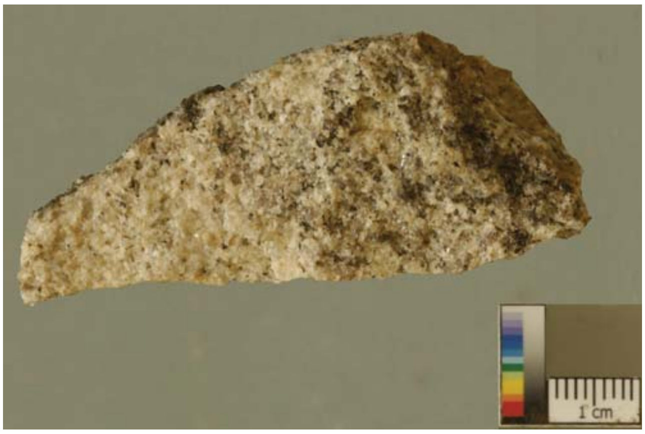
Historical Background

The sample originated from a slab which was used in a rampart in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.



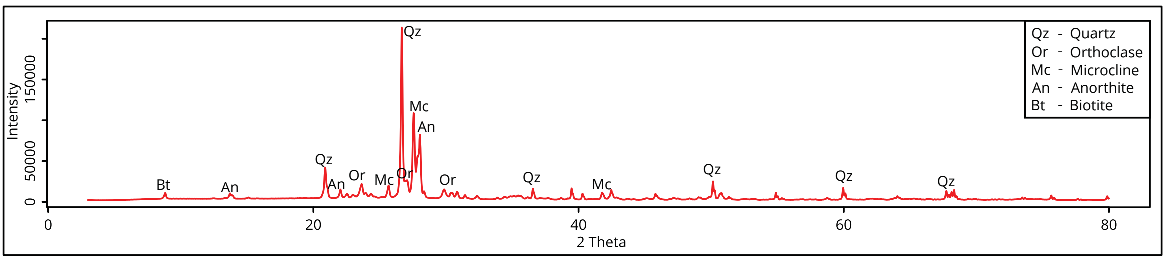
Rock Discription

The fine- to medium-grained pink coloured granitic rock consists of quartz, orthoclase, microcline, plagioclase and biotite. Accessory minerals are ore minerals and zircon.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	74.90	Co	0.01
TiO_2	0.20	V	0.01
Al_2O_3	11.65	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.70	Rb	0.02
MnO	n.d.	Sr	0.02
MgO	n.d.	Y	n.d.
CaO	1.25	Zr	0.02
K_2O	5.71	Nb	n.d.
P_2O_5	0.15	Ba	0.07
LOI	0.47	Ce	n.d.
Total	97.60		



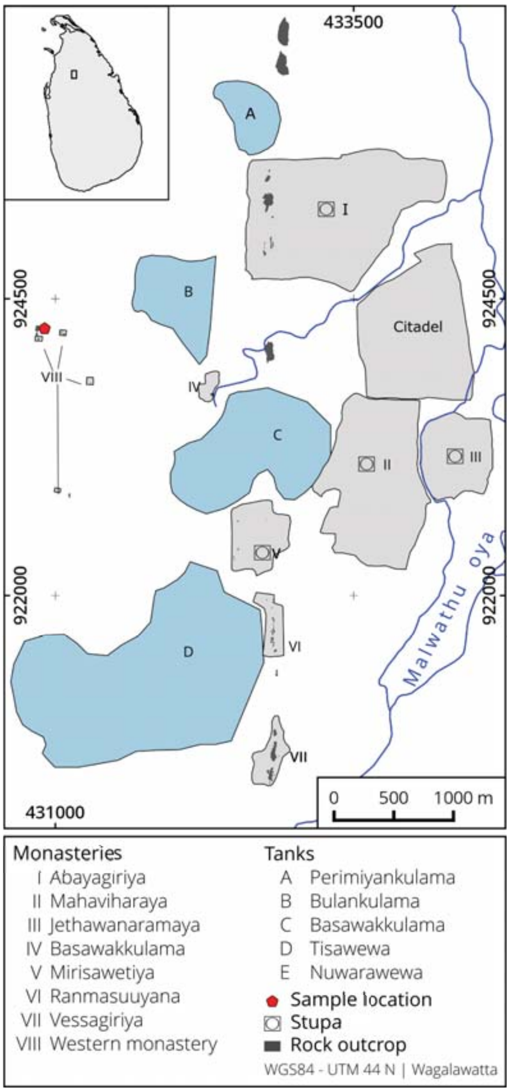
WM.13.Be.

Western Monastery
8°.21'.65" N / 80°.22'.35" E

Source - Ancient quarry
Rock type - Granitic gneiss

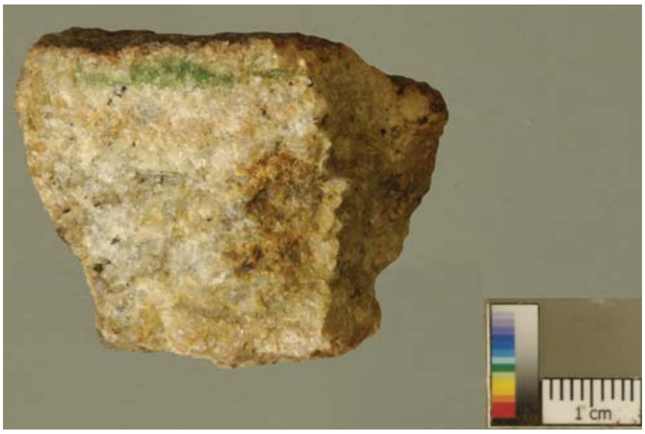
Historical Background

The site is a pit quarry which is located in the western monasteries. The pit is already converted into a pond in order to collect water. Chisel marks are visible on the quarried edges of the parent rock. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.



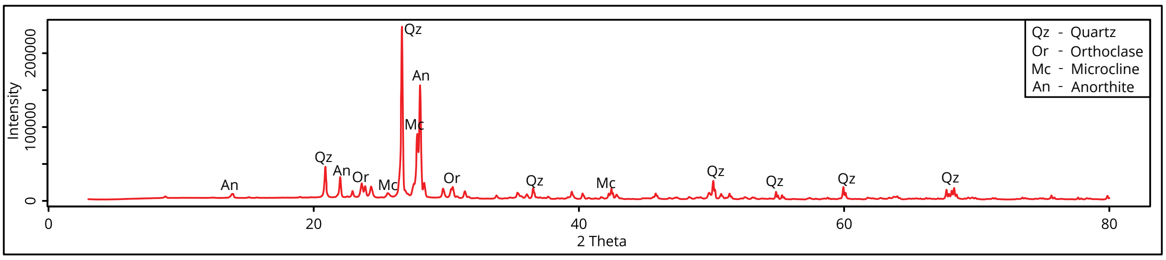
Rock Discription

Fine- to medium-grained less foliated rock is made up of quartz and anorthite with subordinate orthoclase. Mafic minerals such as biotite and hornblende are rarely present.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	70.19	Co	0.01
TiO_2	0.08	V	0.00
Al_2O_3	11.57	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	0.68	Rb	0.00
MnO	n.d.	Sr	0.07
MgO	n.d.	Y	n.d.
CaO	2.94	Zr	0.00
K_2O	1.53	Nb	n.d.
P_2O_5	0.08	Ba	0.08
LOI	1.28	Ce	n.d.
Total	88.35		



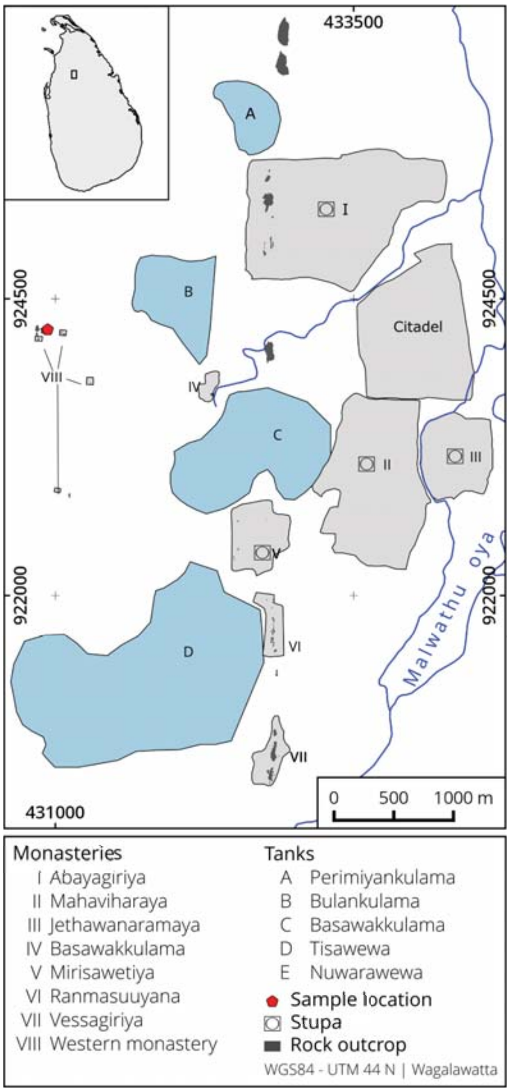
WM.16.Bu.

Western Monastery
8°.21'.64" N / 80°.22'.37" E

Source - Building rock
Rock type - Granitic gneiss

Historic background

The sample originated from a slab which was used in a rampart in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.

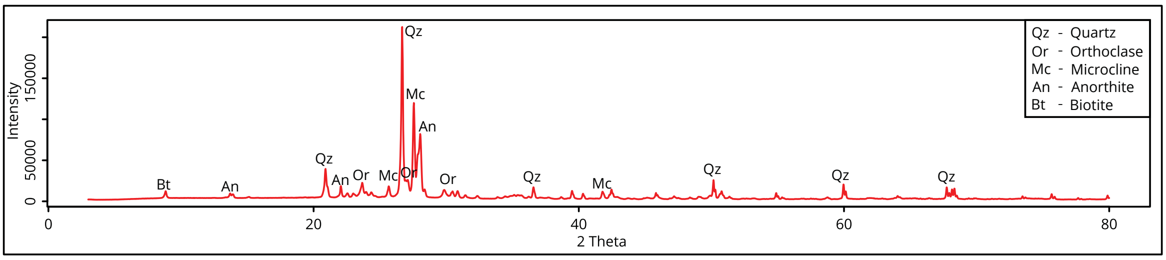


Rock Discription

The fine- to medium-grained rock contains typical major minerals of granite. Fine-grained strongly foliated layers are present.

Chemical Composition (n=1)

Major elements (wt.%)		Trace elements (ppm)	
SiO_2	76.18	Co	0.01
TiO_2	0.23	V	0.01
Al_2O_3	11.64	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.83	Rb	0.03
MnO	n.d.	Sr	0.02
MgO	n.d.	Y	n.d.
CaO	1.25	Zr	0.02
K_2O	5.44	Nb	n.d.
P_2O_5	0.15	Ba	0.06
LOI	0.41	Ce	n.d.
Total	97.11		



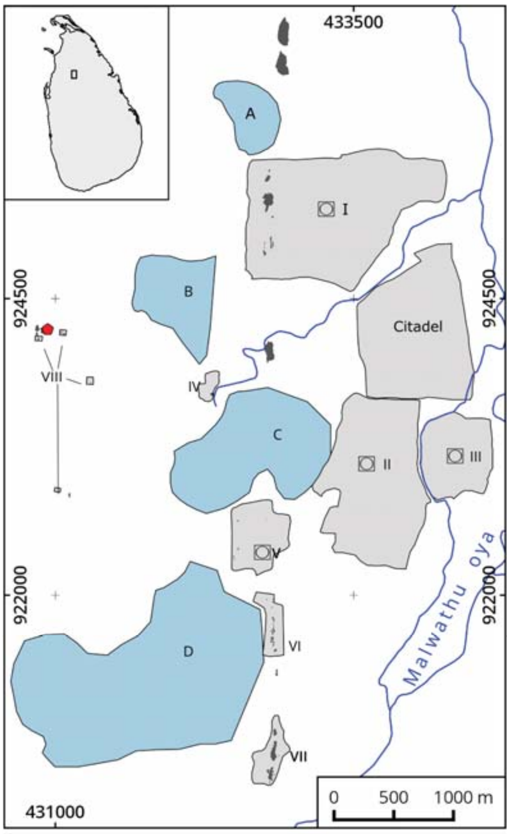
WM.17.Bu.

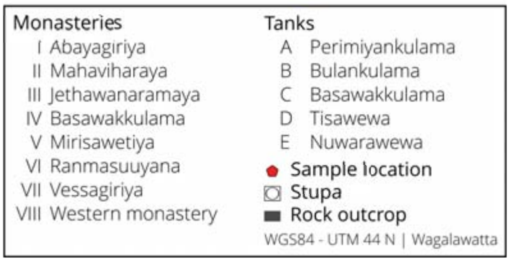
Western Monastery
8°.21'.64" N / 80°.22'.37" E

Source - Building rock
Rock type - Granitic gneiss

Historical Background

The sample originated from a slab which was used for dado decoration of a ruined building in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.



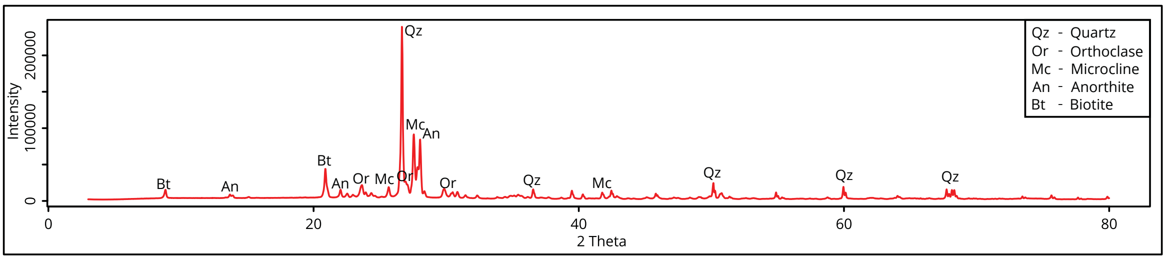


Rock Discription

The fine- to medium grained highly weathered rock contains quartz, microcine and orthoclase as major minerals and plagioclase and biotite as minor minerals.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	77.22	Co	0.02
TiO_2	0.27	V	0.01
Al_2O_3	11.89	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	2.15	Rb	0.02
MnO	n.d.	Sr	0.02
MgO	n.d.	Y	n.d.
CaO	1.36	Zr	0.03
K_2O	5.58	Nb	n.d.
P_2O_5	0.13	Ba	0.06
LOI	0.53	Ce	n.d.
Total	99.15		



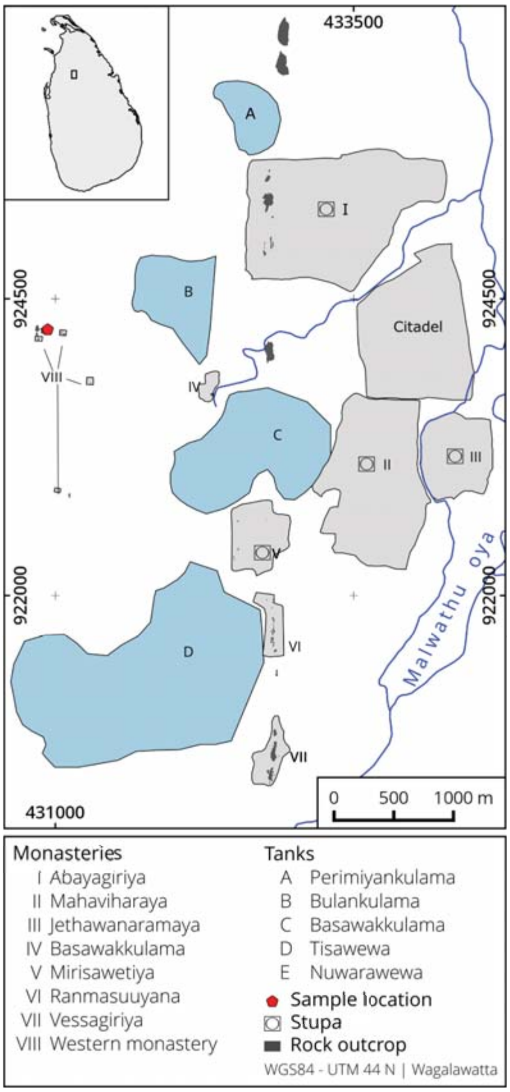
WM.16.Bu.

Western Monastery
8°.21'.64" N / 80°.22'.37" E

Source - Building rock
Rock type - Granitic gneiss

Historical Background

The sample originated from a slab which was used in a wall of a ruined building which is located in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.

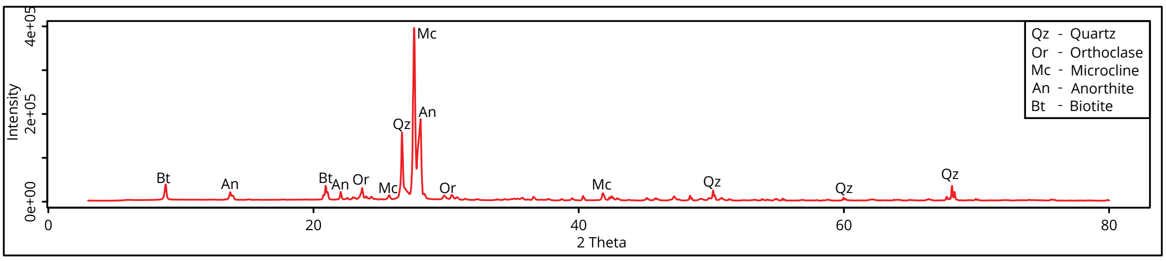


Rock Discription

The fine-to medium-grained rock contains quartz and orthoclase/microcline as major minerals with minor plagioclase and biotite. Sugary texture is the characteristic feature of the specimen.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.86	Co	0.00
TiO_2	0.30	V	0.01
Al_2O_3	11.31	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	2.52	Rb	0.01
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.60	Zr	0.04
K_2O	5.36	Nb	n.d.
P_2O_5	0.11	Ba	0.09
LOI	0.30	Ce	n.d.
Total	85.35		



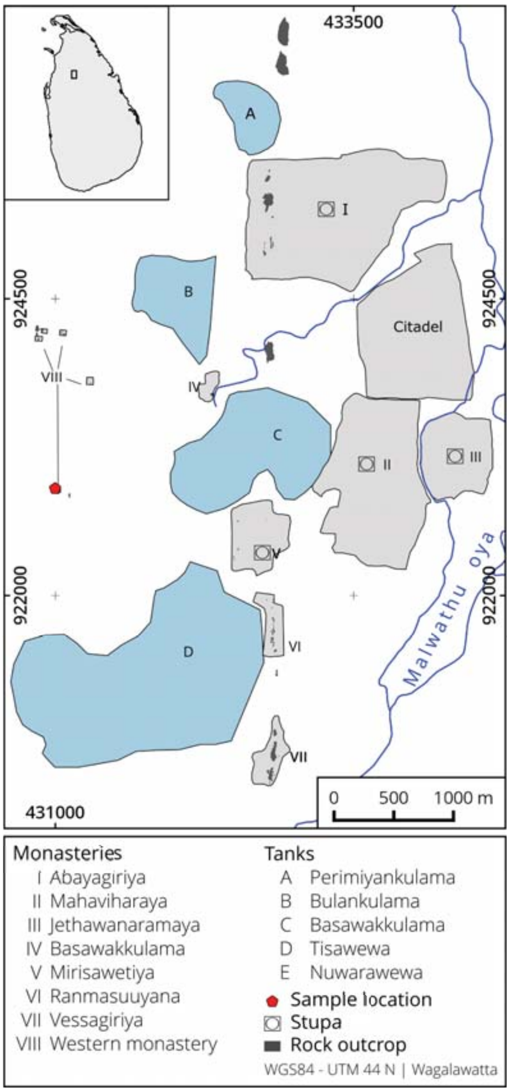
WM.19.Be.

Western Monastery
8°.21'.40" N / 81°.22'.30" E

uoBrce - l Bidgins rock
Rock type - Granitic sneiSS

HiStoricadl acksroBng

Fi n dgc Tsn - emumgan. œ-c g q br. gamr dsgh - qg ebmn. hbrsmnu l irni rds tgan. rn ai n l ndaner c - rgdanemdk Fi n l ndaner c - rgdanemd gen tsbdaned - q . - bhsn Tsgaq ec hbrsmnud s tgan. rn ai n l nda - q ai n irda-em tmf - q Cr beg. i gTbegk Fi ndn c - rgdanemd gen bdbgsf ndaghsmdi n. - r ai n e tof dbegtnd gr. ai nf l nen dbee- br. n. hf g l ganec - gagr. g egc Tgeak

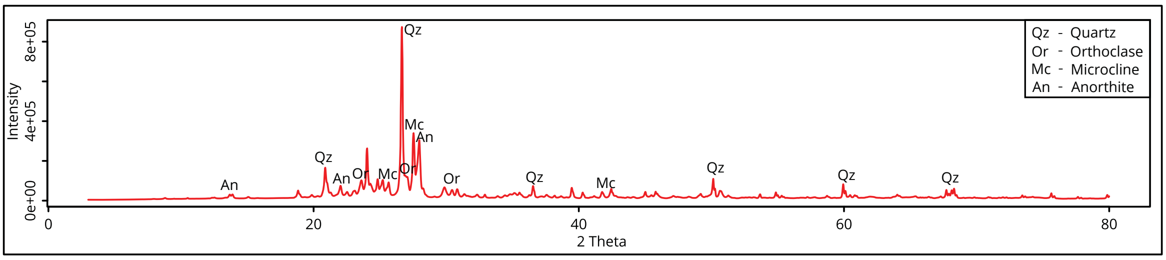


Rock DiScription

Fi n e- to rdu egr ratn unr rddl l rai sgf ned etri rn c gfit c rnnegsdk Fi n uegrn drpn - q ai n e- to rdi rni sf zgengshsn œ-c fir n a- t- gedn uegrnd - q wbgeap gr. Myqns dTgek vmn uegrnn. Tsgurntsgdn - tt bed gd c rn- e c rnnegsk Fi n c gfit ai rn sgf ned gen c g. n c grnsf - qhmarank

ChemicadCompoSition (r =1)

Major elements (wt.%)		Trace elements (ppm)	
AnS o	70k2O	K-	9k9O
FnS o	9k09	V	9k91
CsS 2	11k85	Kb	r k k
vnS	r k k	Zr	9k91
vnS 2	1k85	Rh	9k91
3 r S	r k k	Ae	9k92
3 uS	r k k	Y	r k k
KgS	9k60	Ze	9k92
MS	5k44	Nh	r k k
PS 5	9k11	Bg	9k97
LS I	9k27	Kn	r k k
Total	96.74		



WM.23.Be.

Western Monastery
8°.21'.40" N / 80°.22'.56" E

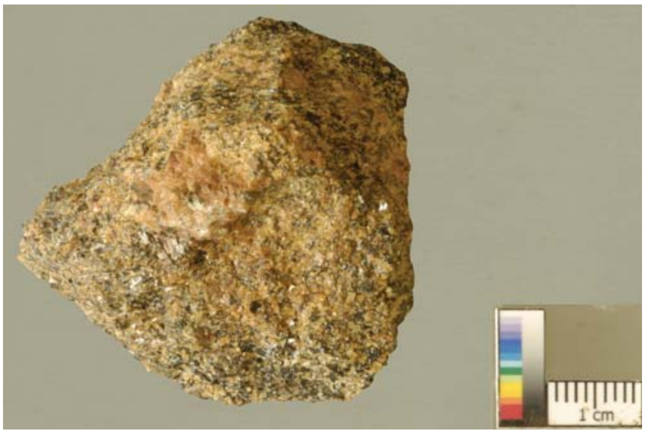
Source - Ancient uarry
Rock type - Hornblende biotite migmatitic gneiss

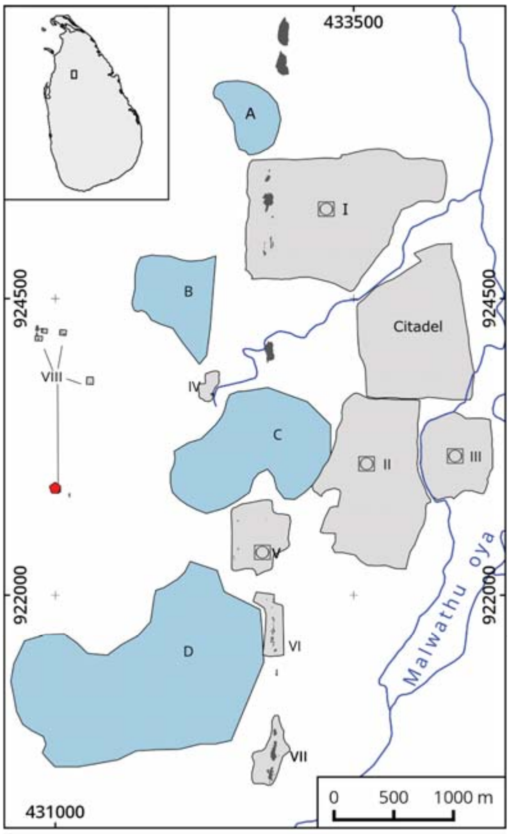
Historical Background

The site is a pit quarry which is located in the western monasteries. The pit is already converted into a pond in order to collect water. Chisel marks are visible on the quarried edges of the parent rock. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.

Rock Discription

Strongly weathered hornblende biotite migmatitic gneiss that contains higher amounts of mafic minerals such as hornblende and biotite. Variable quantities of quartz and plagioclase are present.





Monasteries
I Abayagiriya
II Mahaviharaya
III Jethawanaramaya
IV Basawakkulama
V Mirisawetiya
VI Ranmasuuyana
VII Vessagiriya
VIII Western monastery

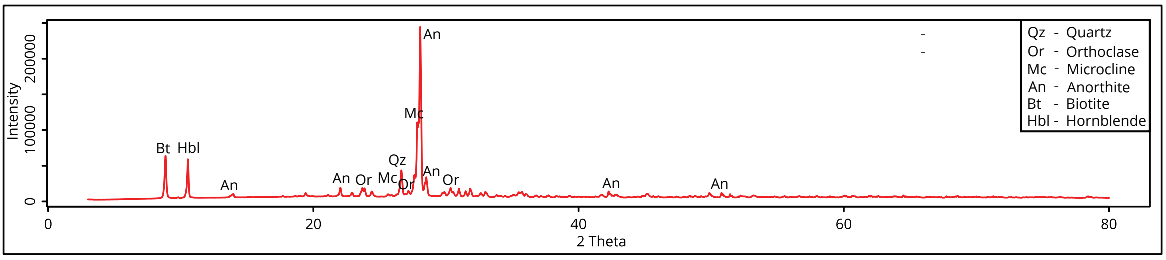
Tanks
A Perimiyankulama
B Bulankulama
C Basawakkulama
D Tisawewa
E Nuwarawewa

Sample location
Stupa
Rock outcrop

WGS84 - UTM 44 N | Wagalawatta

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	46.05	Co	0.00
TiO_2	2.07	V	0.02
Al_2O_3	16.10	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	14.00	Rb	0.00
MnO	n.d.	Sr	0.05
MgO	n.d.	Y	n.d.
CaO	7.79	Zr	0.01
K_2O	1.90	Nb	n.d.
P_2O_5	0.98	Ba	0.12
LOI	0.27	Ce	n.d.
Total	90.30		



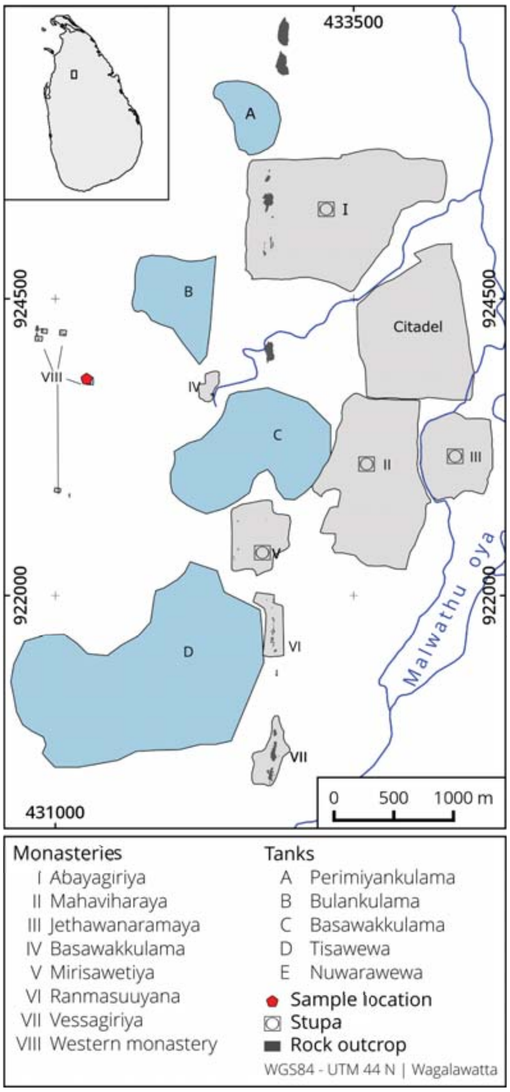
WM.24.Bu.

Western Monastery
8°.21'.43" N / 80°.22'.56" E

Source - Building rock
Rock type - Granitic gneiss

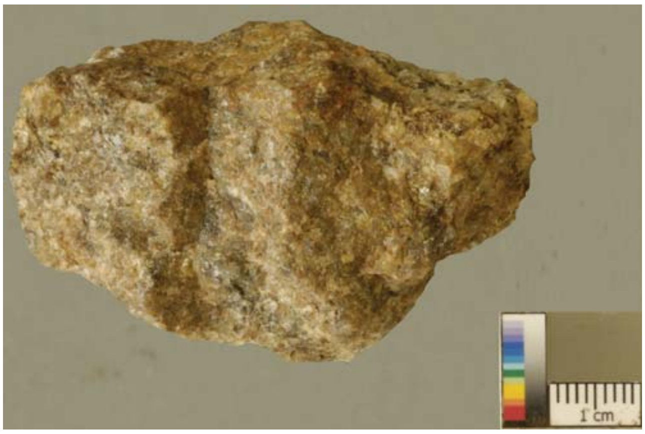
Historical Background

The sample originated from a slab which was used in a rampart in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.



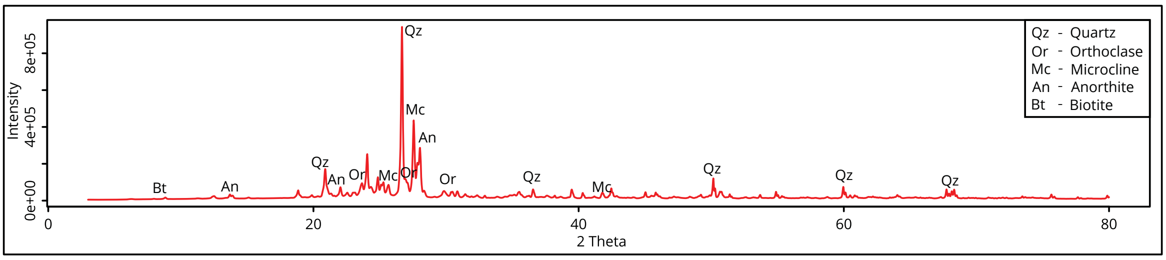
Rock Discription

The medium- to coarse-grained, slightly weathered rock contains quartz, orthoclase, microcline and anorthite as rock forming minerals. Strong layering appearance and the coarse grain nature are the characteristic features of the specimen.



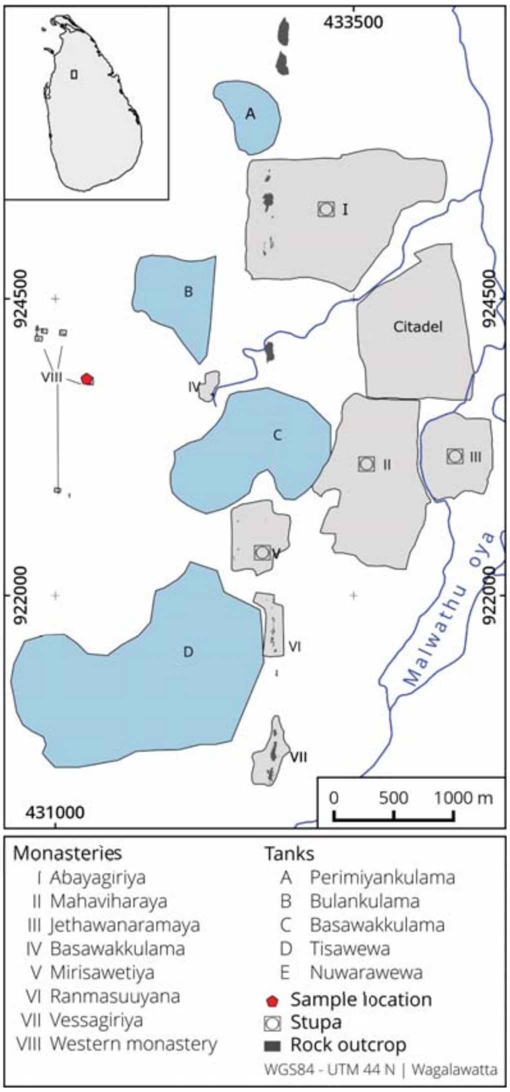
Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	72.40	Co	0.00
TiO_2	0.31	V	0.01
Al_2O_3	11.35	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	3.50	Rb	0.01
MnO	n.d.	Sr	0.02
MgO	n.d.	Y	n.d.
CaO	1.54	Zr	0.03
K_2O	5.01	Nb	n.d.
P_2O_5	0.16	Ba	0.09
LOI	0.84	Ce	n.d.
Total	95.10		



WM.25.Bu.

Western Monastery
8°.21'.43" N / 80°.22'.56" E



Source - Building rock
Rock type - Granitic gneiss

Historical Background

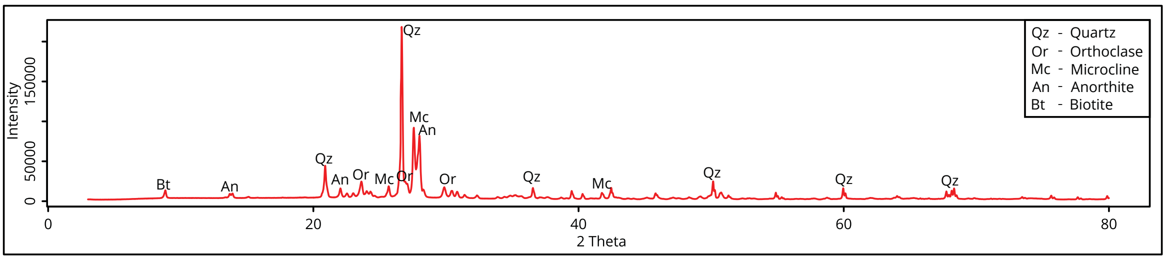
The sample originated from a slab of a terrace wall which is located in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.

Rock Discription

The fine-grained highly weathered rock is made mainly of quartz and K-feldspar (microcline and orthoclase). Minor amounts of plagioclase (anorthite) and biotite are present.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	74.66	Co	0.01
TiO_2	0.16	V	0.01
Al_2O_3	10.84	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	1.59	Rb	0.02
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.11	Zr	0.01
K_2O	5.13	Nb	n.d.
P_2O_5	0.14	Ba	0.08
LOI	0.46	Ce	n.d.
Total	94.09		



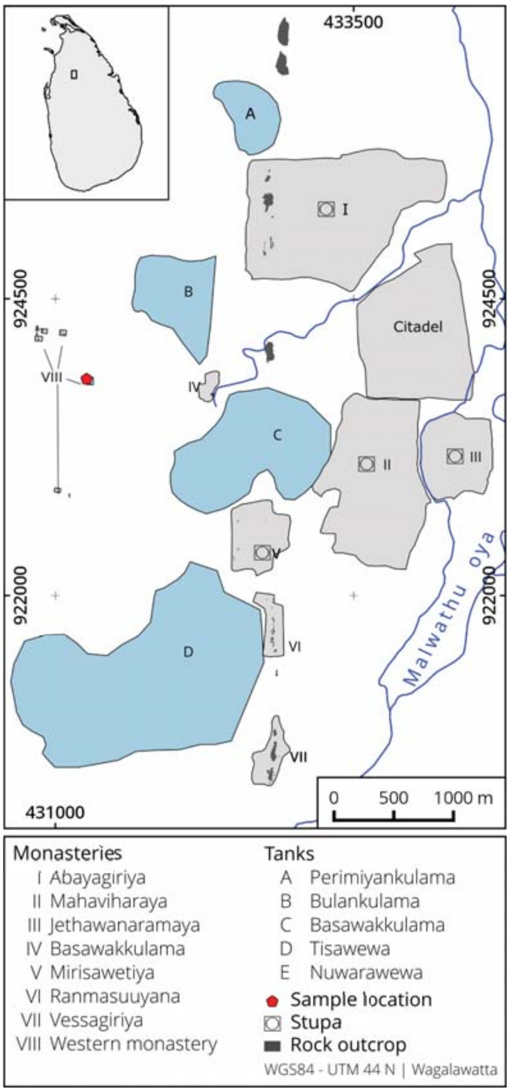
WM.26.Bu.

Western Monastery
8°.21'.43" N / 80°.22'.56" E

Source - Building rock
Rock type - Granitic gneiss

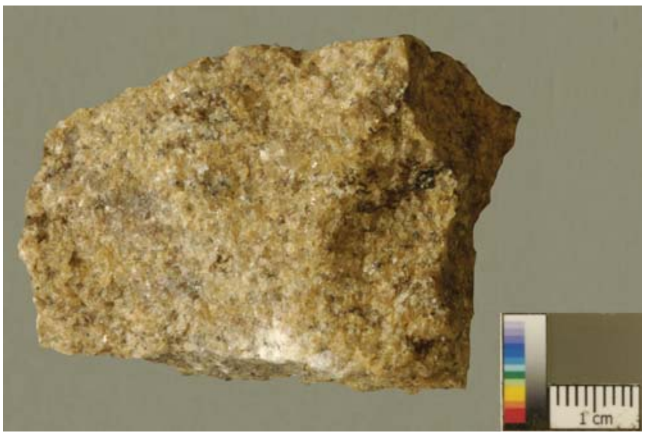
Historical Background

The sample originated from a slab of a terrace wall which is located in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.



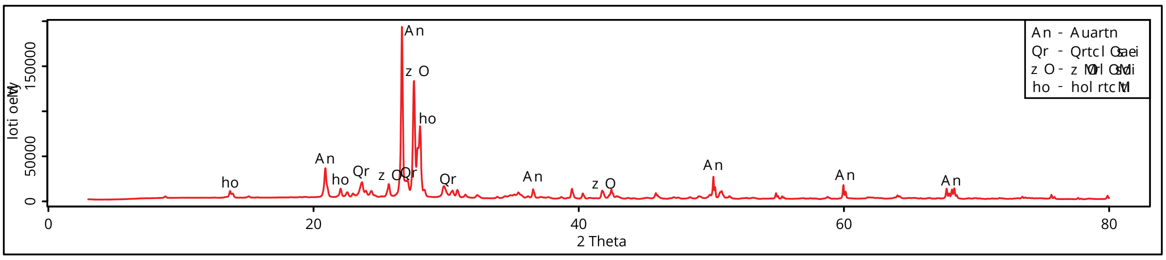
Rock Discription

The fine to medium grained rock show weak foliation and it contains quartz and K-feldspar (orthoclase and microcline) as major minerals with plagioclase and biotite as minor minerals. Due to the weathering the colour of the fresh rock has been altered.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	72.69	Co	0.01
TiO_2	0.28	V	0.01
Al_2O_3	11.21	Cu	n.d.
FeO	n.d.	Zn	0.02
Fe_2O_3	2.88	Rb	0.01
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.37	Zr	0.03
K_2O	5.56	Nb	n.d.
P_2O_5	0.10	Ba	0.08
LOI	0.41	Ce	n.d.
Tl tas	94.49		



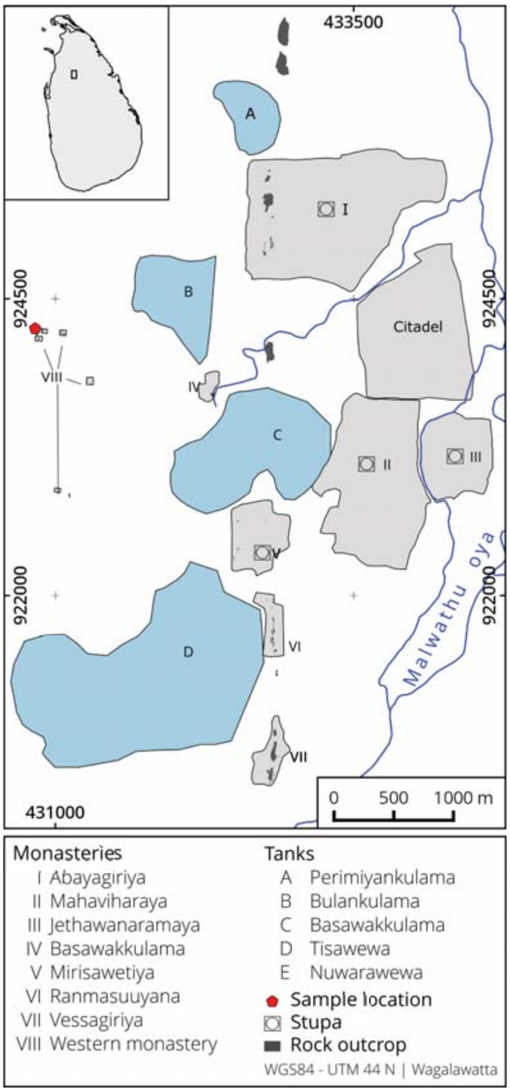
WM.27.Be.

Western Monastery
8°.21'.65" N / 80°.22'.32" E

Source - Ancient quarry
Rock type - Granitic gneiss

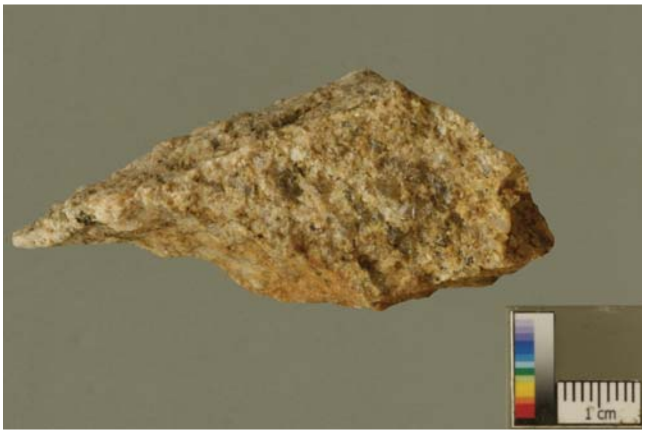
Historical Background

The site is an exposed basement rock area situated in the western monasteries. Ancient chisel marks are existing through the quarried edges of the parent rock. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.



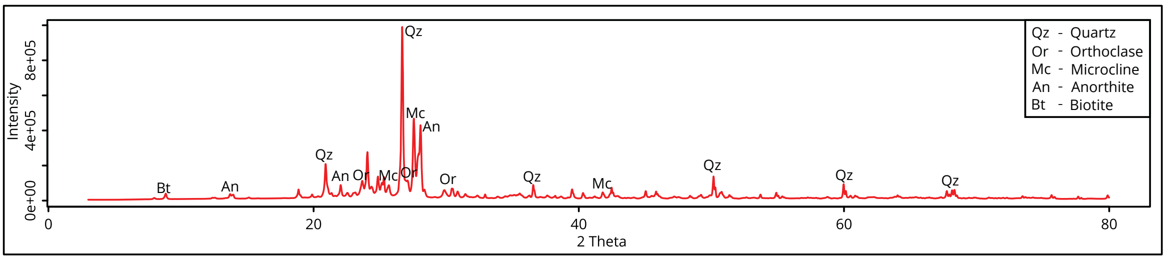
Rock Discription

The light-brown to pink coloured foliated granitic gneiss contains coarse-grained K-feldspar and medium grained quartz in a fine- to medium-grained groundmass of plagioclase (anorthite) and biotite with accessory hornblende.



Chemical Composition (n=1)

Major elements (wt.%)		Trace elements (ppm)	
SiO_2	73.94	Co	0.01
TiO_2	0.18	V	0.01
Al_2O_3	11.15	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.69	Rb	0.02
MnO	n.d.	Sr	0.02
MgO	n.d.	Y	n.d.
CaO	1.29	Zr	0.01
K_2O	5.14	Nb	n.d.
P_2O_5	0.14	Ba	0.06
LOI	0.58	Ce	n.d.
Total	98.35		



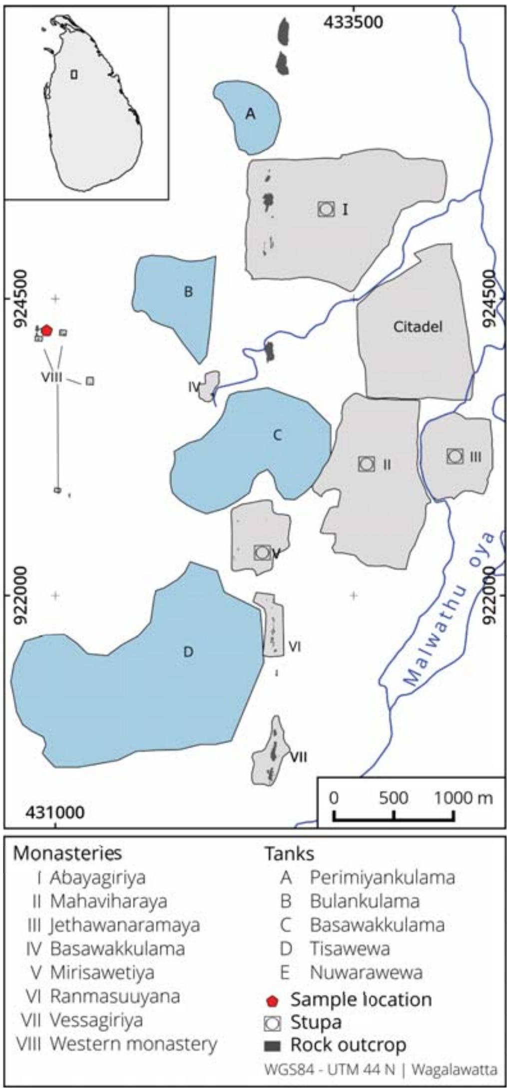
WM.29.Bu.

Western Monastery
8°.21'.65" N / 80°.22'.37" E

Source - Building rock
Rock type - Granitic gneiss

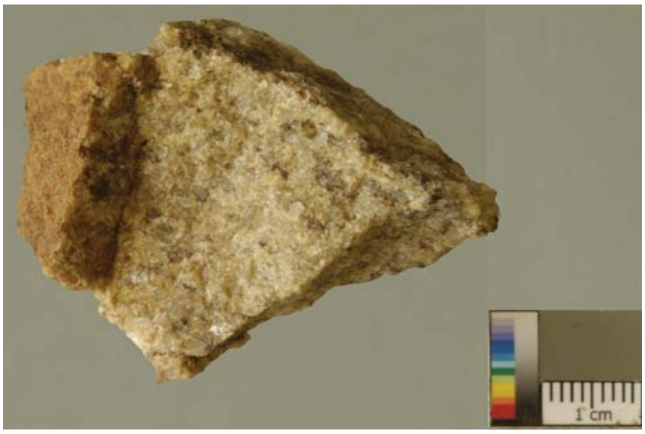
Historical Background

The sample originated from a slab of a terrace wall which is located in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.



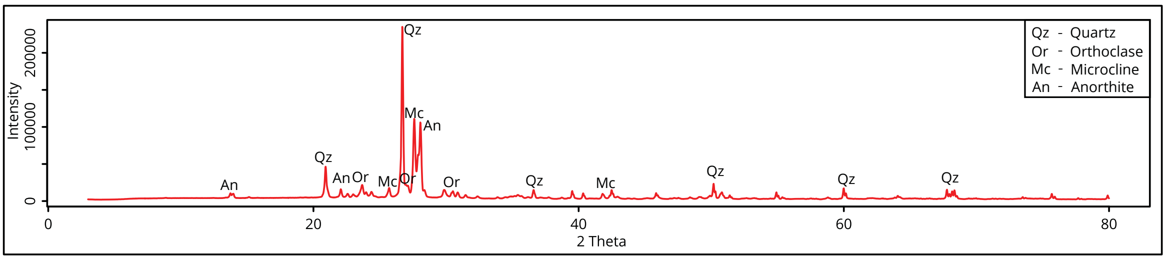
Rock Discription

The brownish gray, medium- to coarse-grained, massive to well-foliated granitoid gneiss composed of quartz, microcline, orthoclase and biotite (as patches). Most of biotite has already been altered.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.13	Co	0.02
TiO_2	0.20	V	0.01
Al_2O_3	10.37	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	2.07	Rb	0.01
MnO	n.d.	Sr	0.02
MgO	n.d.	Y	n.d.
CaO	1.58	Zr	0.02
K_2O	4.48	Nb	n.d.
P_2O_5	0.14	Ba	0.08
LOI	0.69	Ce	n.d.
Total	92.65		



WM.30.Be.

Western Monastery
8°.21'.65" N / 80°.22'.43" E

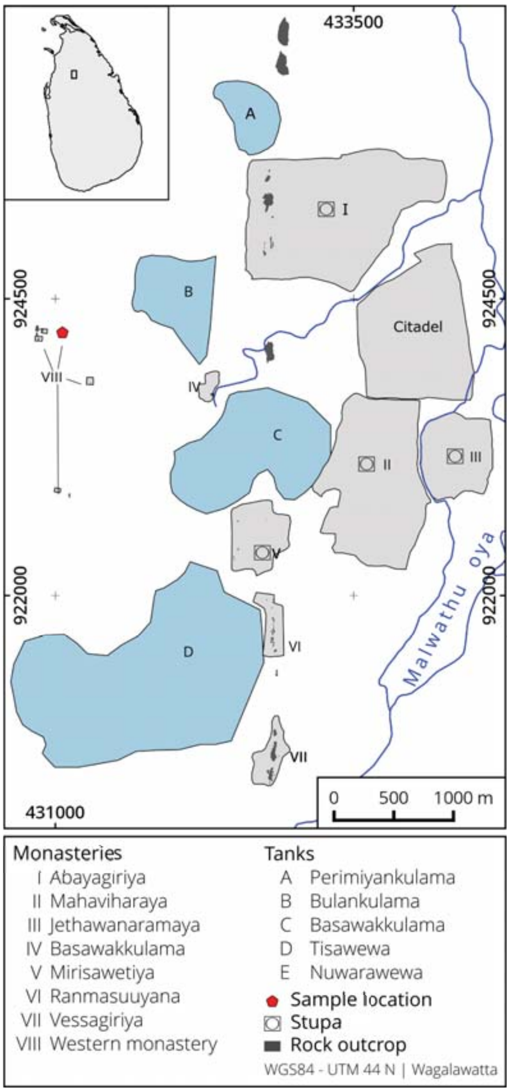
Source - Ancient quarry
Rock type - Granitic gneiss

Historical Background

The site is a pit quarry which is located in the western monasteries. The pit is already converted into a pond in order to collect water. Chisel marks are visible on the quarried edges of the parent rock. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.

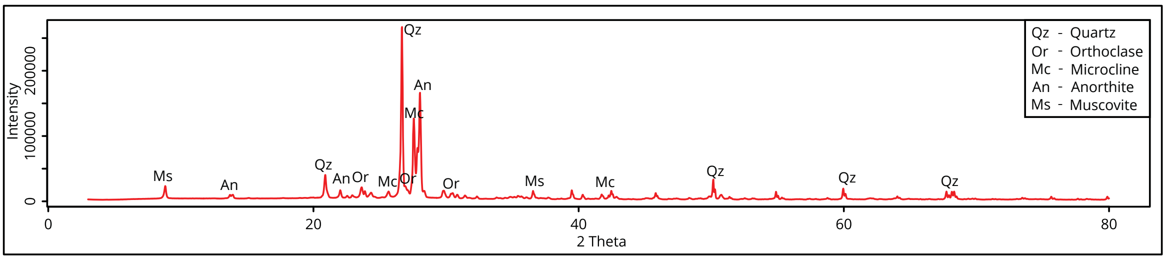
Rock Discription

The light-pink to pink, medium- to coarse-grained, locally porphyritic, variably lineated and foliated gneiss, composed of quartz, microcline, orthoclase, plagioclase and minor biotite, and locally hornblende and muscovite. Lineation formed by rods of quartz.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	73.84	Co	0.02
TiO_2	0.16	V	0.00
Al_2O_3	10.46	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	1.46	Rb	0.02
MnO	n.d.	Sr	0.01
MgO	n.d.	Y	n.d.
CaO	1.10	Zr	0.01
K_2O	5.42	Nb	n.d.
P_2O_5	0.11	Ba	0.06
LOI	0.52	Ce	n.d.
Total	94.08		



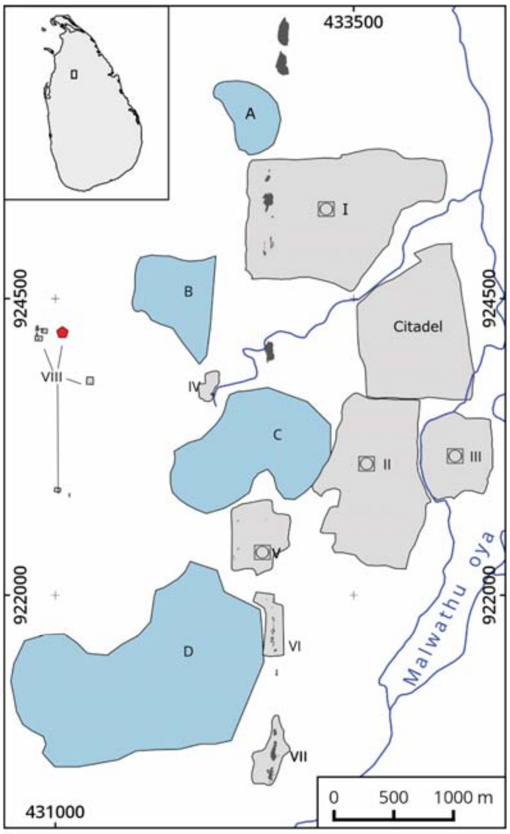
WM.33.Bu.

Western Monastery
8°.21'.43" N / 80°.22'.56" E

Source - Building rock
Rock type - Granitic gneiss

Historical Background

The sample originated from a slab of a terrace wall which is located in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.



Monasteries		Tanks	
I	Abayagiriya	A	Perimiyankulama
II	Mahaviharaya	B	Bulankulama
III	Jethawanaramaya	C	Basawakkulama
IV	Basawakkulama	D	Tisawewa
V	Mirisawetiya	E	Nuwarawewa
VI	Ranmasuuyana		Sample location
VII	Vessagiriya		Stupa
VIII	Western monastery		Rock outcrop

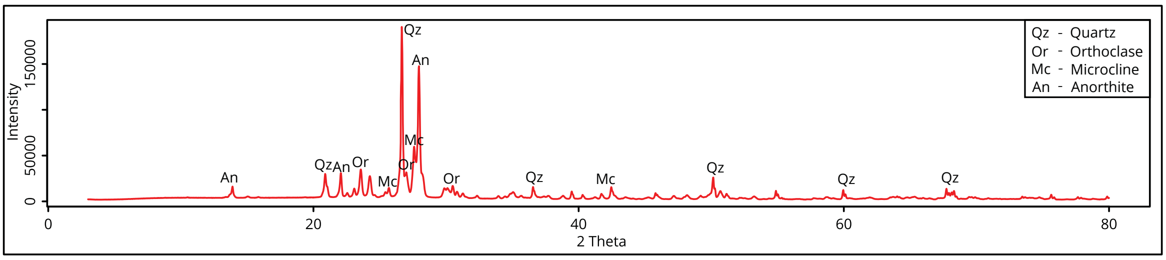
WGS84 - UTM 44 N | Wagalawatta

Rock Discription

The pink, generally non-foliated granitic gneiss, composed of quartz, microcline, orthoclase and plagioclase as major rock forming minerals. Muscovite and biotite are the minor constituents.

Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	69.64	Co	0.01
TiO_2	0.20	V	0.01
Al_2O_3	10.17	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	0.57	Rb	0.01
MnO	n.d.	Sr	0.13
MgO	n.d.	Y	n.d.
CaO	0.52	Zr	0.00
K_2O	3.86	Nb	n.d.
P_2O_5	0.07	Ba	0.16
LOI	0.34	Ce	n.d.
Total	8. 358		



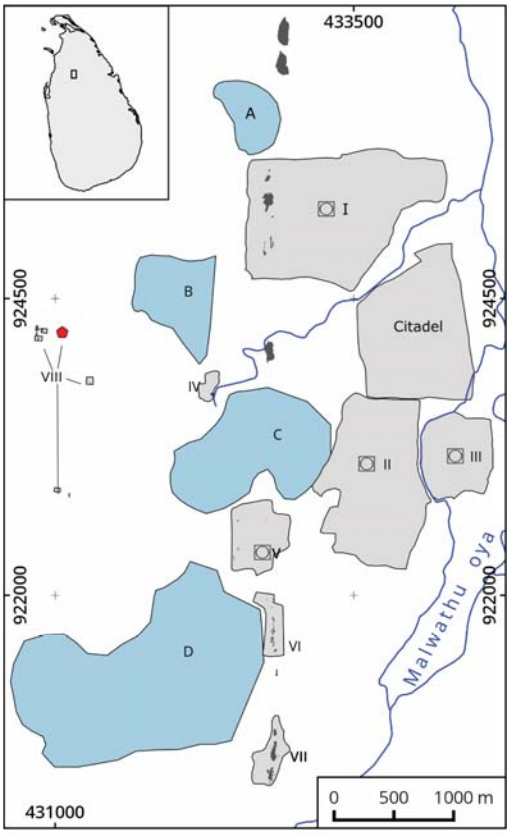
WM.24.Bu.

Western Monastery
8°.21'.43" N / 80°.22'.56" E

Source - Building rock
Rock type - Granitic gneiss

Historical Background

The sample originated from a slab which was used in a rampart in the western monasteries. The western monasteries are clusters of double platform buildings located in the west of the historic city of Anuradhapura. These monasteries are usually established on the rocky surfaces and they were surrounded by a water moat and a rampart.



Monasteries
I Abayagiriya
II Mahaviharaya
III Jethawanaramaya
IV Basawakkulama
V Mirisawetiya
VI Ranmasuuyana
VII Vessagiriya
VIII Western monastery

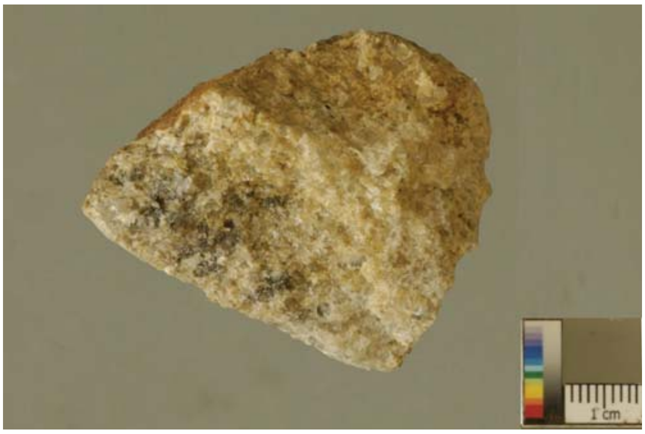
Tanks
A Perimiyankulama
B Bulankulama
C Basawakkulama
D Tisawewa
E Nuwarawewa

Sample location
Stupa
Rock outcrop

WGS84 - UTM 44 N | Wagalawatta

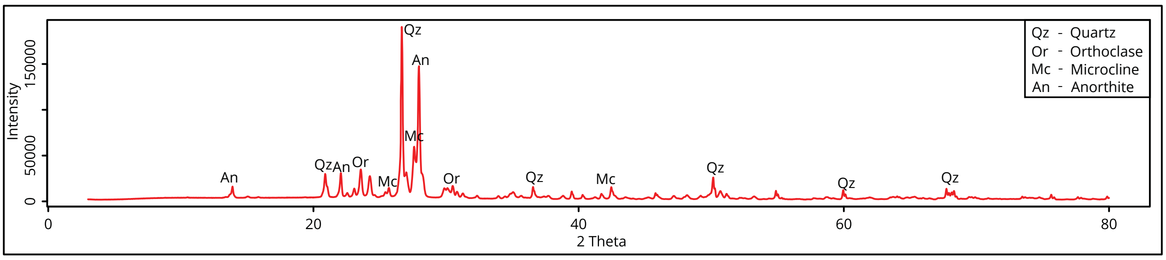
Rock Discription

The highly weathered medium to coarse grained white-gray coloured rock consists of quartz, orthoclase and microcline with minor plagioclase and biotite. Some parts of the rock is massive, but some areas are foliated and have accessory hornblende.



Chemical Composition (n=1)

Major elements (wt.%)		*Trace elements (ppm)*	
SiO_2	76.95	Co	0.02
TiO_2	0.22	V	0.02
Al_2O_3	10.79	Cu	n.d.
FeO	n.d.	Zn	0.01
Fe_2O_3	0.45	Rb	0.01
MnO	n.d.	Sr	0.04
MgO	n.d.	Y	n.d.
CaO	0.95	Zr	0.01
K_2O	5.90	Nb	n.d.
P_2O_5	0.12	Ba	0.19
LOI	0.53	Ce	n.d.
Total	95.91		



A.3. Curriculum vitae

Der Lebenslauf ist in der Online-Version
aus Gründen des Datenschutzes nicht enthalten.

Thusitha Wagalawatta

Yativilla, Weuda
Sri Lanka
+49 71 8025 340
thusitha.wagalawatta@fu-berlin.de

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Eidesstattliche Erklärung

Hiermit erkläre ich, dass ich die Dissertation *Management & Functional Use of Mineral Resources in Ancient Sri Lanka: Stone as A Building Material in Ancient Anuradhapura* selbständig angefertigt und keine anderen als die von mir angegebenen Quellen und Hilfsmittel verwendet habe.

Ich erkläre weiterhin, dass die Dissertation bisher nicht in dieser oder in anderer Form in einem anderen Prüfungsverfahren vorgelegen hat.

Berlin, den   Thusitha Wagalawatta

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