بسم الله الرحمن الرحيم

وزارة التربية والتعليم

اللجنة الوطنية الأردنية للتربية والثقافة والعلوم

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الموافق

URGENT

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Subject: World Heritage List: Wadi Rum Protected Area (Jordan)
Additional Information

Dear Ms. Durighello,

With reference to your letter No. GB/MA1377 dated 22/9/2010 regarding the above mentioned subject.

Kindly find enclosed the additional information needed for the nomination file of Wadi Rum Protected Area.

We would like to express our appreciation to ICOMOS's role in advancing the protection of the cultural values around the world.

Looking forward to hearing from you about any arrangements in this regard.

Please accept the assurances of my highest considerations.

Chairman of J.N.C
Minister of Education
K. Karaki
Prof. Khaled Al- Karaki

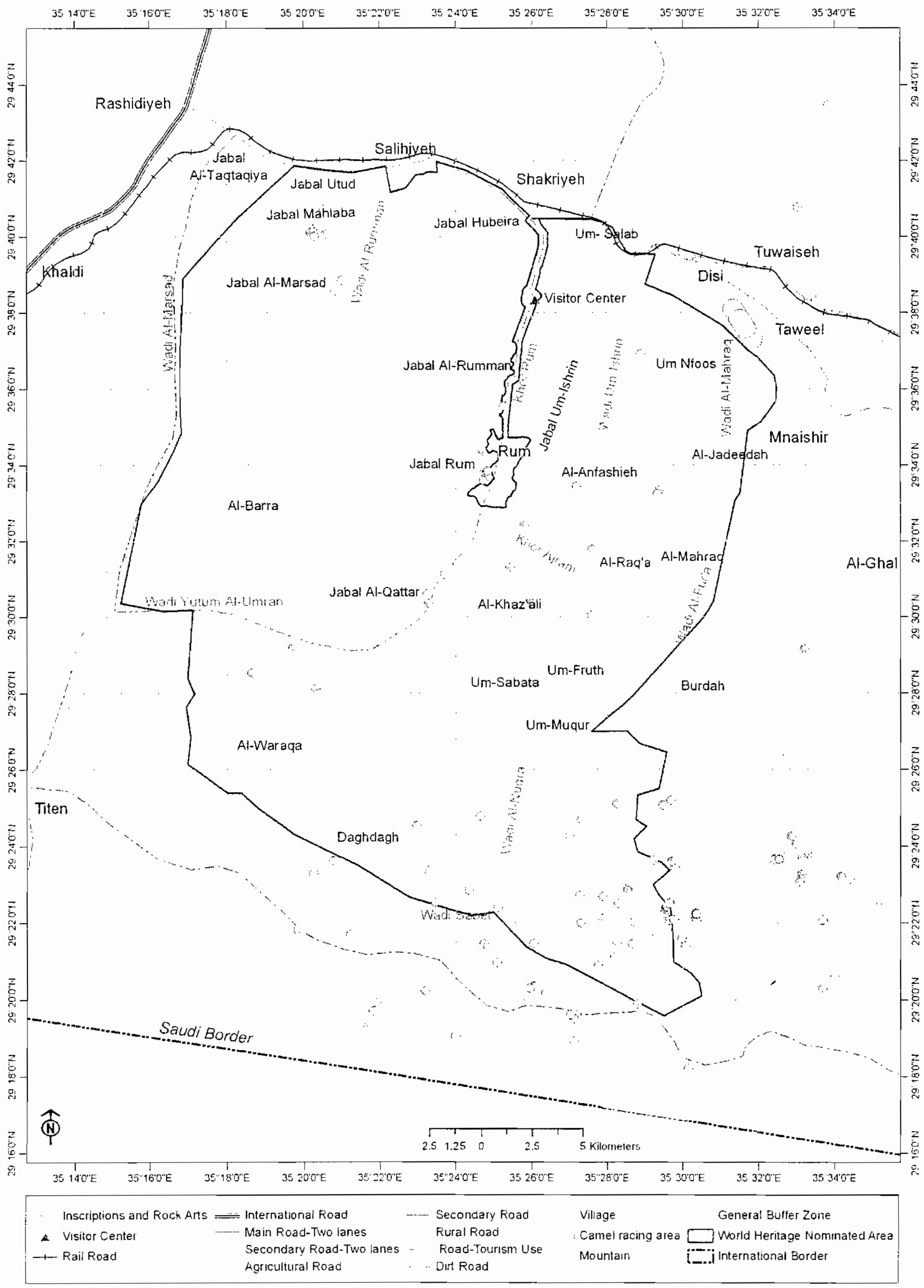
November 5th 2010

Inquiries sent from ICOMOC on September 22nd 2010 Reference GM/MA 1377
Deadline for the Jordanian Government response is November 8th 2010

Detailed response and clarification on inquiries:

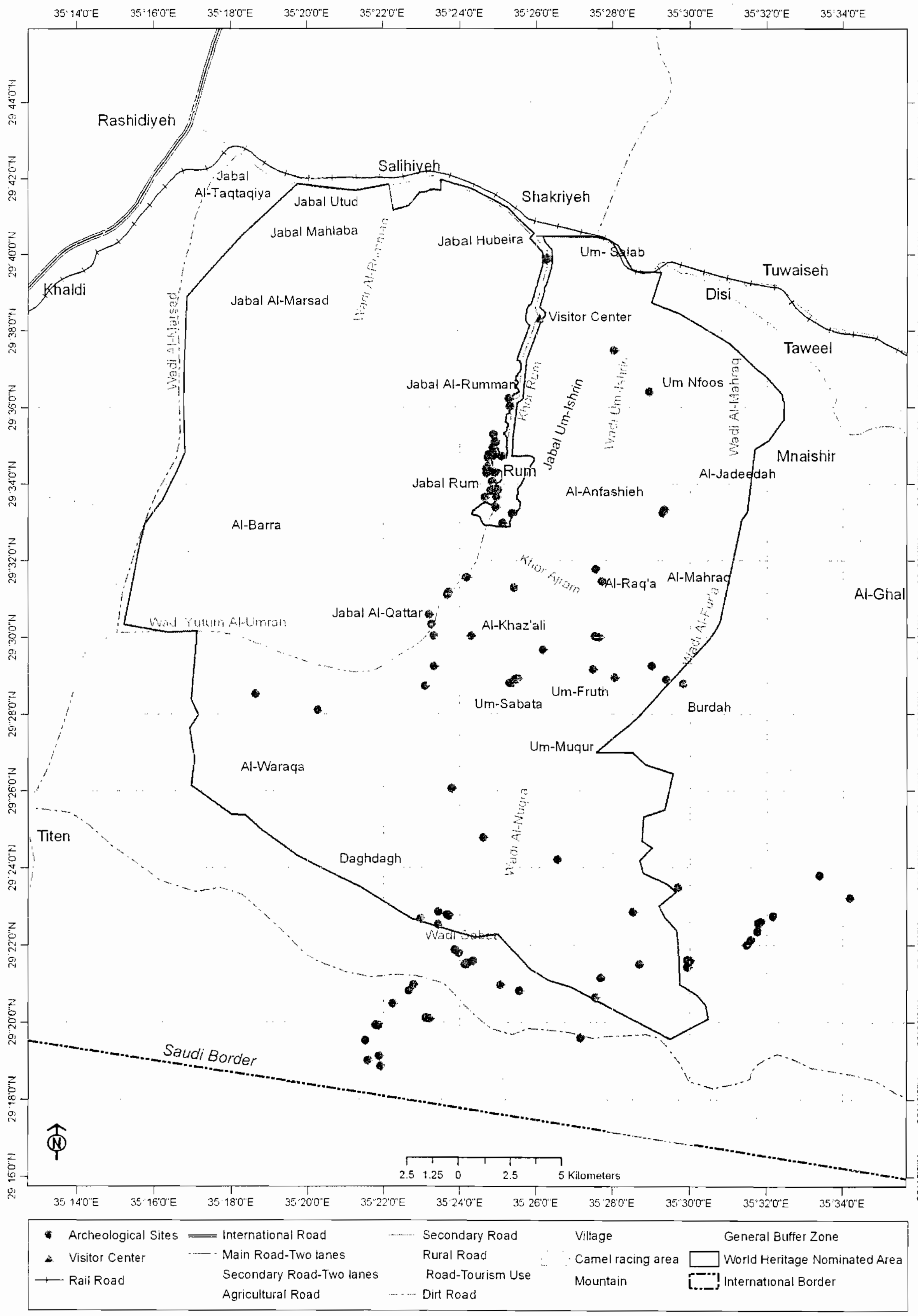
Inquiry 1: Maps of key sites

a- Inscriptions and rock art in the Wadi Rum Protected Area



-Important note: all key sites are located within the proposed property or within the designated buffer zone.

b- Map of key Archaeological within Wadi Rum Protected Area and buffer Zone



-Important note: all key sites are located within the proposed property or within the designated buffer zone.

<u>Inquiry 2:</u> The justification for the exclusion of the land strip from the nominated property

A national workshop was organised on October 1st 2010 to address buffer zone boundaries and the exclusion of the land strip from the visitor centre to Rum village in response to ICOMOS inquiry and the following were the key notes concluded by the Jordanian authorities:

a – The exclusion of the strip from the visitor centre to Rum village:

- The meeting confirmed that the strip was excluded from the proposed property to avoid compromising the nomination file due to the existing level of infrastructure and activities before the nomination process. Nonetheless, if UNESCO and the advisory bodies deem necessary that the strip should be included in the nominated area, the government of Jordan will be ready to do so and make necessary adjustments to the nomination file.
- The excluded strip does not however include the surroundings of Rum village especially those related to archaeological sites namely, the temple, and Abu Nkhaielh site and other associated rock art and inscriptions. The strip is only limited to the visitor centre, the main road with 50meter buffer on both sides collectively and the Rum village area limited to the official village structural plan.
- Even if the strip remains out of the nominated property, it will still fall under the specific by-law of Wadi Rum Area as it was part of the area covered in the legal designation of the protected area in 2002. The strip – in this case – will also remain under the ASEZA general environment protection bylaw mentioned in point one above and the special national law on antiquities number 21 of 1988.
- It is important to note that ASEZA was granted – as part of law – the execution of the department of antiquities law; it does that through a close institutional coordination at the local and national levels through the department of antiquities head in Aqaba and through the direct coordination with the department headquarters in Amman.

b - The arrangement for the buffer zone:

- The meeting agreed to unify the map for the buffer zone as a single geographical area, see attached Map. The buffer zone protection and sustainability come primarily from applying the special environment protection by-law implemented by ASEZA. The bylaw includes a very thorough and strict EIA process which will ensure the minimization of the impacts of all proposed or existing projects and activities I am attaching a copy of the bylaw herewith.

<u>Inquiries 3 and 4:</u> Most significant archaeological sites in the Wadi Rum Protected Area and their authenticity

a- Importance and authenticity of the sites

The key sites within the protected area boundaries and buffer zone:

- Testify to the continuity and density of human occupation since Prehistory;
- Document continuous use and development of water catchment and storage systems that have allowed a variety of human activities;
- Document these activities: permanent settlements, religious sites and beliefs, practise of hunting, farming, herding, and trading (caravans);
- Provide an important selection of rock art and inscriptions from the Palaeolithic to the

Islamic era showing continuity;
- Allow to compare early Islamic written sources with authentic archaeological remains and epigraphical sources as regards the identification of Wadi Rum with Quranic Iram and the presence of the tribe of 'Ad.

b- List and brief description of sites

A- The core area in the valley of Rum comprising of major religious sites:
  - (1) The Allat temple complex (with baths) where the most important Thamudic inscription mentioning the tribe of 'Ad was found ("By Ghawt, the son of Awslh, son of Tkm and he built the sanctuary of Allat, of [the tribe of] al-'Ad").
  - (2) Above the temple, the Ain Shallaleh spring with carvings of the pre-Islamic goddess and god Allat and Dushara, and a Nabatean inscription mentioning the place-name Iram ("May be remembered Hayan, son of 'Abdallahi, son of Ibn 'Atmu, in front of Allat, the goddess of Iram, forever").
  - (3) The eastern slopes of Jabal Rum 2 km before and 2 km after the village of Rum (until Abu 'Aina spring), and the south-western slope of Jabal Umm Ishrin from the village to the tip of the mountain. Along this corridor 22 pre-Islamic shrines have been surveyed (composed of square or rectangular stone enclosures with a betyle -- or stone representing the dwelling of the divinity-- standing in the middle).

B- Associated to the core area:
  - (4) The Abu 'Aina spring and its Thamudic inscriptions on a boulder.
  - (5) The large Neolithic settlement of Abu Nkhayleh with stone mortars testifying to farming activities.
  - (6) The Khaz 'Ali canyon and its rock art and inscriptions covering a period ranging from Prehistory to the Islamic era and mentioning caravans.
  - (7) The Ain al-Qattar spring and the associated elements below (Thamudic inscriptions on a large boulder mentioning the tribes of 'Ad and Shaqalat, and a name similar to the one mentioned on the foundation stone of the temple of Allat; there are also traces of a Neolithic settlement, and a large Islamic graveyard).

C- Peripheral areas:
  - (8) Al Qusayr: large Nabatean dam with associated inscription "Allat the goddess which is at Iram".
  - (9) Jabal Mughra (agricultural area): around this small mountain range eleven dams with numerous Thamudic inscriptions have been documented. Several of these dams are still in use by bedouin herders today.
  - (10) Udayb ar-Rih (agricultural area): large Neolithic agricultural settlement (traces of olive farming) with very ancient hydraulic installations and occupation attested (pottery) until Abbasid period. Hydraulic installations still used by bedouin livestock herders today. Numerous examples of rock art from Prehistorical to Historical periods, and several Thamudic inscriptions.
  - (11) Wadi Rumman (hunting area): important site of rock art with geometric signs, feet and hands, animal and hunting scenes superimposed on two large boulders.

D- Buffer Zone:
  - (12) Ruwais Salim (agricultural area probably connected to site 9): right on the boundary of the Protected Area, large Neolithic agricultural settlement with hydraulic installations and large number of petroglyphs and Thamudic inscriptions.
  - (13) Jabal Burdah: major Nabatean dam with inscriptions.

E- Beyond buffer zone:
  - (14) Jabal Kharrazeh (agricultural area and caravan station): 15km to the north

of the Protected Area, major Nabatean hydraulic installations (several dams) and caravan outpost between the two Nabatean settlements of Rum and al-Humayma. The site also has important traces of Prehistoric occupation (large carved human figures and other petroglyphs).

Important note: although Jabal Kharrazeh is beyond the buffer zone, in view of its importance and relation to the site of Wadi Rum it would be important to include it in the management plan as the object of special protection measures by ASEZA and the Department of Antiquities.

Inquiry 5: Active conservation and maintenance programs

a- Protection of Antiquities: legal and regulatory environment

The protection of archaeological sites in the Wadi Rum Protected Area falls under the Jordanian Law of Antiquities n.21 (1988) that applies to all movable and immovable antiquities throughout the Kingdom. Antiquities are defined as "any movable or immovable object which was made, written, inscribed, built, discovered or modified by a human being before the year AD 1750" and "human, animal and plant remains which date back before AD 600" (Art. 2, 7 a & b).

All immovable antiquities are the property of the state; the state is also the proprietor of all the antiquities found during excavation work carried out by licence (Art. 5; Art. 21, b).

The law regulates building and other activities (industries and quarries) in the vicinity of archaeological sites (Art. 13). It also prohibits and sets punishments for trading in antiquities (Art. 23), unlicensed excavations (Art. 14), and damages to antiquities (Art. 9).

Under the Minister of Tourism and Archaeology, the Department of Antiquities is entrusted, inter alia: to ensure the protection, maintenance and repair of antique sites (Art. 3, a, 3); carry out surveys and excavations and deliver special licenses for surveys or excavations to scientific institutions (Art. 16); render assistance in organizing museums pertaining to Government activities (Art. 3, a, 6); and co-operate with local, Arab and foreign archaeological groups who serve the national heritage and spread archaeological awareness (Art. 3, a, 7).

In the Wadi Rum Protected Area, the Antiquity Law is further reinforced by the regulations of the Protected Area and the by-laws of the Aqaba Special Economic Zone.

b- Enforcement

The Antiquity law and Protected Area regulations pertaining to antiquities are enforced by the Protected Area Management in collaboration with the Directorate of Antiquities of the Aqaba Governorate. As mentioned before in this report, ASEZA – under its 2000 law – was granted the delegation to enforce the national antiquities law within and framework for institutional coordination and collaboration with the department of antiquities at the local and national levels.

The enforcement of the protection and preservation of the archaeological sites within the protected area and buffer zone of Wadi Rum is undertaken by the ranger force of the protected area who are technically trained and logistically equipped to perform the assignment with the maximum level of efficiency and effectiveness.

Inquiry 6: **Roles and activities of the Department of Antiquities**

The Department of Antiquities is represented in the Aqaba Governorate by Dr Sawsan Fakhry.

In keeping with its mandate, the Department of Antiquities has, over the past 15 years, licensed three missions to conduct excavations and surveys in the Wadi Rum Protected Area:

- A US mission led by Thomas Parker (North Californian State University) to excavate and study the Neolithic settlement of Abu Nkhayleh (mid-1980s to mid-1990s);
- A Canadian mission led by Dennine Dudley and Barbara Reevis (University of Victoria) to excavate and study the bath complex near the temple of Allat (late 1990s);
- A Franco-Jordanian mission led by Saba Farès (University of Lyon) and Fawzy Zayadin (Jordanian Department of Antiquities) to conduct a complete survey of inscriptions and associated sites, and to excavate the Neolithic settlement of Udayb er-Rih (ongoing since 1996).

Other activities of the Department of Antiquities in recent years have included:

- Performing restoration work at the temple of Allat and baths complex;
- Authorizing the fencing of the sites of Udayb er-Rih and Abu Nkhayleh;
- Lending artefacts to the interpretation room at the Visitor Centre and contributing interpretation material;
- Delivering licenses to foreign teams;
- Collaborating with teams during their mission through the presence of an inspector;
- Facilitating their logistical needs and relations with the authorities;
- Conserving the material found during surveys and excavations;
- Publishing preliminary mission reports in the Department's periodical (*ADAJ-Annals of the Department of Antiquities of Jordan*);
- Keeping a data base of site locations, names and particulars;
- Collaborating with archaeological organisations such as the Jordanian Friends of Archaeology to conduct lectures about and site visits in the Wadi Rum Protected Area to spread awareness of the area's importance.

Planned activities include:

- Improving signage and interpretation of major sites in the core area (Allat temple complex, Shallaleh spring, Abu 'Aina spring, Abu Nkhayleh settlement);
- Conducting a comprehensive archaeological mapping in the buffer zone to list sensitive areas and protect them in line with the Law of Antiquities and the bylaws of ASEZA.
- Collaborating with the Aqaba Special Economic Zone Authority to provide artefacts for the museum displaying the findings of the Franco-Jordanian mission to be created in the Visitor Centre;
- Producing a copy of the foundation stone of the temple of Allat to put it in place while the original will be conserved in the museum;
- Establishing a nucleus for a centre for archaeological studies focusing on the world heritage related values and characteristics of the Wadi Rum protected area.
- Devise a cultural conservation and maintenance strategy as part of the anticipated management plan of the protected area.
- Design and implement a comprehensive capacity building program for local staff of ASEZA and the department of antiquities on the protection of the world heritage cultural values of Wadi Rum.

<u>For contact information:</u>

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End of report ...

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04 January 2011

IUCN Evaluation of the "Wadi Rum Protected Area" (Jordan) – Request for Supplementary Information

Dear Ambassador,

The IUCN World Heritage evaluation mission to "Wadi Rum Protected Area" was undertaken by Prof. Kyung Sik Woo and Ms Zoe Wilkinson on behalf of IUCN (jointly with Dr Majeed Khan on behalf of ICOMOS) from 18 September to 27 September 2010. The evaluators greatly appreciated the excellent support and co-operation provided by your colleagues in the preparation and implementation of the mission, and the kind welcome of the State Party throughout the mission.

The IUCN World Heritage Panel met in Gland, Switzerland, in December 2010 and the findings of the mission and other inputs have now been considered by the Panel.

As noted in previous correspondence, IUCN seeks to develop and maintain a dialogue with States Parties during the evaluation process. Following the discussions of the IUCN World Heritage Panel we would thus like to kindly ask for clarification of the points listed hereafter:

1. Geological Information supporting criteria viii
During the mission the evaluators requested, and were provided with, a presentation from an appropriate expert in Jordanian geology to supplement the information provided in the nomination file. This presentation highlighted key information relevant to the nomination under criteria viii. IUCN recommends that the nomination file would be strengthened through the provision of a written summary of this supplementary information. In addition the comparative analysis of the values being nominated under criteria viii would also benefit by being re-orientated around this supplementary information.

2. Boundary and Buffer Zone
IUCN notes that the boundary of the nominated property does not correspond exactly with the boundary of the Wadi Rum Protected Area. Whilst the rationale for defining the boundary of the nominated property to exclude the settlement of Rum and the road leading to this is acknowledged it is arguable that the integrity of the property would be better served without this exclusion.

IUCN commends the inclusion of a buffer zone for the nominated property however it was noted that the regulations for the Wadi Rum Protected Area do not currently cover the buffer zone. In order to have an effective buffer zone consistent with the Operational Guidelines IUCN recommends that the Wadi Rum Protected Area Regulations be modified to include regulation of the buffer zone. From a technical perspective, such an increase could positively influence the integrity and facilitate more effective management. IUCN would welcome the State Party's observation in regard to the above points.

3. Management Planning

IUCN notes that a comprehensive management planning process is now underway to replace the outdated management plan for Wadi Rum Protected Area. IUCN commends the state party for this and would be grateful for an update on the status of the new management plan and the timescale for its completion. IUCN would further welcome details of how the management plan will be linked to a business plan including budgets for implementation. Given the Operational Guideline require World Heritage properties to have an effective management system, IUCN would be most grateful for advance copies the management plan and associated business plan as soon as they become available.

We would appreciate your response to the above points as soon as possible, in order to facilitate the evaluation process, but **no later than the 28 February 2011**, as per paragraph 148 of the Operational Guidelines. Please note that any information submitted after this date will not be considered by IUCN in its evaluation for the World Heritage Committee. It should be noted, however, that while IUCN will carefully consider any supplementary information submitted, it cannot properly evaluate a completely revised nomination or large amounts of new information submitted at the last minute. So we request to keep your response concise and respond only to the above requests.

Supplementary Information should be submitted officially in three copies to the UNESCO World Heritage Centre in order for it to be registered as part of the nomination. An electronic copy of any supplementary information to both the UNESCO World Heritage Centre and IUCN Headquarters would also be helpful.

Taking into account your response, IUCN will formulate its final recommendation to the World Heritage Committee which will meet from 19 to 29 June 2011 in Bahrain.

Please do not hesitate to contact Mr. Tilman Jaeger, World Heritage Project Management Officer, if you have any questions with respect to this request for supplementary information (Tel: + 41 22 999 0158; Fax: +41 22 999 0025; Email: tilman.jaeger@iucn.org).

Let me again reiterate our thanks for your support of the World Heritage Convention and for the conduct of the recent mission. We look forward to your kind cooperation in furnishing responses to the abovementioned points.

Yours sincerely,

Tim Badman
Head - World Heritage Programme

Cc. Jordan National Commission for UNESCO, Ms Toujan Bermamet, Secretary-General
UNESCO World Heritage Centre, Ms Véronique Dauge and Mr Alessandro Balsamo
IUCN Regional Office for West Asia, Dr. Odeh Al Jayyousi , Regional Director
Ministry of Environment, Hussein Shahin, Director, Nature Protection,
Tarek Abul Hawa, National Technical Coordinator
ICOMOS, Regina Durighello, Trina Ramos

Mr. Tim Badman
Head – World Heritage Programme
IUCN
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1196 Gland
Switzerland

Reference:
Date:

Subject: IUCN evaluation of "the Wadi Rum Protected Area" (Jordan) – Request for supplementary information

Dear Mr. Badman

In reference to IUCN's letter dated January 4th 2011 in regard to the request for supplementary information on "the Wadi Rum Protected Area" World Heritage Nomination file, kindly find herewith our response to your letter along with the requested supplementary information:

1. **Geological Information Supporting Criterion viii:**

The following supplementary information is attached in four separate additional notes as follows:

- Note on the protected area geology and its associated comparative analysis.
- Note on the protected area landscape evolution.
- Note on the landscape and human occupation
- Note on the activity of climbing and its relevance to the landscape.

2. **Boundary and Buffer Zone:**

The boundary of the nominated areas has been re-adjusted to include the full size of the protected areas as defined in the Wadi Rum protected area by-law and without the exclusion of the land strip form the visitor centre to Rum village. Attached herewith is the final map of the proposed nominated property with the respective surface areas of the different management zones within the PA proper and the buffer zone.

As for the protected area buffer zone, a special review of the Wadi Rum Protected Area bylaw and associated regulations and bylaws relevant is currently underway. The review will include a set of new and amended regulations and articles which will govern the land use planning and management of the buffer zone around the protected area proper to ensure the enhanced control and the minimal impacts of the development activities currently taking place or planned for the future. The first technical draft of the review is currently being submitted for legal review by the Aqaba Special Economic Zone Authority and is expected to be finalized and legally endorsed by the end of June 2011.

3. Management Planning

The process of the development of the new updated management plan is underway. A special national team of experts supported by a team of international experts are putting together the new management plan for the protected area in light of its natural and cultural values using the guidelines and best practices adopted by UNESCO, IUCN and ICOMOS.

The full draft of the new management plan and its associated tourism development and visitor management plans are expected to be finalized and endorsed by the government of Jordan by the end of March 2011. The management plan will include a specific conservation plan for both the natural and cultural heritage of the area. The management plan will be part of the business planning process of the Aqaba Special Economic Zone Authority and will be integral to its annual budgetary allocation. To ensure this, a special business plan of the area will be developed as part of the management planning process.

The business plan will include the breakdown of expected management costs and income generated through the various activities including site visitation. Covering the costs of the implementation of the management will be primarily the responsibility of the Aqaba Special Economic Zone Authority supported by its national and international partners and donors agencies. The following table summarizes the adopted action plan in regard to the management plan preparation process.

No	Action	Deadline
1	Develop the first draft of the core technical reports on the management of natural heritage, cultural heritage and the visitors management	March 15th 2011
2	Develop the first draft of the consolidated management plan 2012 – 2016	April 1st 2011
3	Undertake stakeholders' consultation on the draft plan	May 1st 2011
4	Prepare and submit the final draft of the management plan to ASEZA	June 1st 2011
5	Endorse the final management plan by the Wadi Rum management committee and ASEZA	June 30th 2011

We hope that you find these supplementary information in line with your request, please do not hesitate to contact us is more information or clarification is needed.

Allow us again to thanks your esteemed organization for your valuable support and cooperation on safeguarding our region's and the world's natural and cultural heritage. We look forward to meet you in Bahrain.

Sincerely yours,

Dr. Taher Al Shakhshir

Minister of Environment

بسم الله الرحمن الرحيم

وزارة التربية والتعليم

اللجنة الوطنية الأردنية للتربية والثقافة والعلوم

الرقم 49/3/2 9151

التاريخ 28 /2/2011

الموافق

URGENT

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Subject: IUCN Evaluation of the "Wadi Rum Protected Area" (Jordan)-Request for Supplementary Information

Dear Mr. Bandarin,

Kindly find enclosed the additional information needed for the nomination file of Wadi Rum Protected Area.

We would like to express our appreciation to all parties who have contributed in advancing the protection of the cultural values around the world.

Looking forward to hearing from you about any arrangements in this regard.

Please accept the assurances of my highest considerations.

Yours Sincerely.

J.N.C.
Secretary General

Toujan Bermamet

THE HASHEMITE KINGDOM OF JORDAN ★ Ministry of Education

cc/ H.E. The Minister of Environment
cc/ H.E. Dina Kawar, Permanent Delegation of Jordan to UNESCO

تلفون: ٥٦٨٣٨٧٤/ ٥٦٨٤١٣٧ ـ ٦ ـ ٠٠٩٦٢ فاكس: ٥٦٨٨٠٦١ ـ ٦ ـ ٠٠٩٦٢ ص.ب: ١٦٤٦ عمان ١١١١٨/ الأردن

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Wadi Rum Protected Area Geology – Additional Note

1. Lithology of the sandstone sequence in Wadi Rum area

The rocks within Wadi Rum Protected Area consist of two main types: granitoids of the Precambrian and sandstones of the Early Paleozoic. These are separated by a peneplain representing a prolonged unconformity between the two types.

1.1. Precambrian Basement

The Precambrian basement, in Wadi Rum Protected Area (WRP) consists predominantly of plutonic igneous rocks of the larger granite family; e.g. including granite, granodiorite, quartz monzonite…etc. The basement is subdivided into two complexes: the older Aqaba Complex (630-600 Ma) and a younger Araba Complex (600-540 Ma). The Aqaba Complex has a calcalkaline composition while the Araba Complex is alkali to peralkali in nature. Due to their mineralogy, granitoids are colorful, red – grey, especially in the NW of the WRP.

1.2. Early Paleozoic Sandstone Sequence

The granitoid basement is overlain with a clastic sedimentary regime in excess of 1500 m in thickness. The sequence was named the "Nubian Sandstones" by early workers (e.g. Hull, 1886; Blankenhorn, 1914. The clastic regime is now subdivided into two groups (Powell, 1989):

1. Upper or Khreim Group-Ordovician - Early Silurian, is not represented in the WRP, and thus is not discussed further.
2. Lower or Rum Group-Cambrian - Early Ordovician is completely confined to Wadi Rum Protected Area. It is around 1000 m thick and consists of four formations from younger to older:
   - Umm Sahm Formation, Lower Ordovician
   - Disi Formation, Lower Ordovician
   - Umm Ishrin Formation, Middle-Upper Cambrian
   - Salab formation, Lower Cambrian

Following is a brief description of the lithology of the four formations.

1.2.1 Salab Formation

The Salab Formation, after Gaa Umm Salab (Gaa, Arabic for inland mud-silt flat), is Lower Cambrian in age, 40-50 m thick, and was deposited by braided rivers flowing northwards into the Tethys Ocean. It forms the base of the Rum Group overlying the peneplain of the Precambrian Basement

It consists of redish, yellow, brown, and white pebbly sandstones to sandy conglomerates. The basal part consists of localized, well-rounded, quartz conglomerates filling the low reliefs of the peneplain of the topmost Precambrian basement. The roundness and the absence of granitoid pebbles derived from the underlying basement indicate a prolonged erosion and a long distance source for the basal conglomerates (Powell, 1989). The rest of the formation consists of two alternating facies: pebbly, coarse-grained sandstone facies and fine-grained, micaceous sandstone facies. The latter predominates towards the upper part of the formation. The sandstones are arkosic near the base becoming sub arkosic further up. Towards the top of the formation, fine-grained, micaceous sandstones with ***Skolithos*** burrows can be seen (Amireh et al., 1994). Fig. 1 is a columnar section of the formation near Qaa' Salab at the NW of the WRP.

The bedforms as well as the lithology produce a step-like, well-bedded weathering morphology. Trough cross-bedding with lag pebbles and graded forests dominates the bedforms. Trough cross-beds are some times overturned or convoluted. Planar to ripple cross laminations are present in the fine micaceous sandstones towards the top of the formation. Various types of cross bedding show a unidirectional paleocurrent generally to the north.

1.2.2 Umm Ishrin Formation

The name is after the type locality, Jabal Umm Ishrin and Gaa' Umm Ishrin in the northeastern part of the WRP (Abd Elhamid, 1988)). The WRP displays the best outcrops of Umm Ishrin Formation. Here, it is massive with red, brown, violet and pink weathering colours. High vertical cliff with long vertical joints are characteristic. The ancient Petra city was carved in the Umm Ishrin Formation. The age of Umm Ishrin Formation ranges from Middle to Late Cambrian (Bender, 1974; Powell, 1989).

The thickness of the Umm Ishrin Formation, within the WRP, is around 320m. The formation is made of medium to coarse-grained quartz arenite sandstones, is medium cemented by quartz overgrowth and/or calcite stained with hematite. Quartz grains are sub rounded and well sorted. It has no beds of quartz pebbles or conglomeratic beds. However, pebbles can be seen at the base of the trough cross bedding and channels. Minor, thin beds of red siltstones are also present.

Lensoidal bedding, after channel fill, is the main type of bedding in this formation. Lenses are massive and vary in thickness from 1m to several metres and can be several hundred metres in length (Selley, 1972; Bender, 1974). They are characteristic of the formation. Trough cross beds are the main primary sedimentary structures within these lenses. These troughs are sometimes overturned or convoluted especially in the lower part of the formation. The paleocurrent direction, taken from cross-bedding, is generally to the north (Powell, 1989). Fig. 1 shows a columnar section near the type section within the WRP.

The depositional environment of the Umm Ishrin Formation is essentially of fluvial braided river environment in a humid climate (Selley, 1972; Amireh et al., 1994). Evidence for this interpretation are the lack of fossils in the formation, unidirectional paleocurrent, and medium to large scale trough cross-bedding, some times overturned, with pebbles at trough base. The mineralogical maturity and sorting may indicate a provenance situated to the south of Jordan.

1.2.3 Disi Formation

The name is after Gaa' Disi at the northeastern part of the WRP where the type section of the formation is measured. It is Early Ordovician, Arenig, in age, 300-350 m thick of a rather soft and the least cemented quartz arenite in the sandstone sequence (Fig. 1). Disi consists of white sand that came from a different source than that of the red sand below, and is washed out of colour due to prevailing different climates at that time. Silica (SiO_2), as quartz, can reach up to 99% at certain horizons of the formation. That is why it is used as glass sand in some outcrops further north of the WRP. The sparse cement types are quartz overgrowth, dickite/kaolinite, and some calcite.

The upper end of this layer contains some trace-fossils called ***Cruziana***, which were created by an extinct marine animal called trilobite. These fossils tell us that when the highest summits were deposited, Wadi Rum was covered by shallow waters of the Tethys Ocean.

Weathering colour is white to grey-white, but in fresh sample it is normally snow white. The formation consists of medium to coarse-grained quartz arenite which is slightly cemented. Well-rounded quartz pebbles, up to few centimeters, are present at the base of the trough cross beds and scattered throughout the formation. Two siltstone-shale horizons up to 4 m thick with ***Cruziana*** traces are present in the upper part of the formation, indicating a marine transgression within the dominantly braided river sedimentary environment..

Lensoidal bedding after large scale trough cross-bedding and channels dominates the bedforms in this formation. Lenses can be several metres thick and several hundreds metres in length. Upon weathering, these lenses produce a typical domal appearance characteristic of the Disi Formation. However, tabular cross bedding is also present. Parallel bedding is present in the two siltstone-shale horizons in the upper part of the formation. Paleocurrent direction is essentially towards the north.

"The grain size, lithological maturity, bedforms and unimodal paleocurrent flow suggest that the Disi Formation was deposited predominantly as large scale subaqueous dunes in high velocity, high discharge braided rivers, similar to those of the underlying Umm Ishrin Formation" (Powell, 1989).The well-rounded quartz pebble and the mineralogical maturity indicate distant provenance. The change in colour from red-brown for the underlying Umm Ishrin to the snow white Disi Formation might due to change in provenance and /or change in climate to a wetter climate (Selley, 1972; Powell, 1989; Amireh, et al., 1994).

1.2.4 Umm Sahm Formation

This is the uppermost formation in the Rum Group. Only the lower part of the formation crops out within the WRP. Its name is taken after Jabal Umm Sahm at the extreme SE of the WRP. It is Early Ordovician, Arenig, in age, 230-250 m thick, and is distinguished by its dark brown weathering colour, parallel bedding, steep cliffs and relatively more indurated silica sandstones.

Lithologically, Umm Sahm Formation consists of brown weathered, grey-brownish, medium to coarse grained, well-cemented and indurated quartz arenites (Fig. 1). Although the formation is characterized by parallel bedding, "Three types of bedforms or lithofacies can be recognized in this formation: a) Trough cross bedded granule-rich medium to coarse-grained sandstone with occasional overturned forests in tabular sets. This lithofacies is similar to the Disi Formation below. b) Plannar cross bedded medium to coarse grained sandstone in thin 10-30 cm sets. This lithofacies is typical for Umm Sahm Formation. c) Heterogenous, trace fossil-rich, 0.5-8 m thick, green, red, grey, rippled and rippled cross laminated or plannar cross laminated, is represented in 3 to 4 horizons in the formation. Various types of ripples are present. Trace fossils are abundant in this lithofacies; e.g. ***Cruziana sp***., ***Harlania sp***. and ***Skolithos*** (***Sabellarefix***)" (Powell, 1989).

The Disi-like lithofacies are abundant in the lower part of the formation and alternate with the typical Umm Sahm type lithofacies, indicating a gradual change in the depositional environments from fluvial to shallow marine. The trace fossil horizons are present within the middle and upper part of the formation.

The trace fossils mentioned above indicate deposition in a shallow marine, possibly tidal environment. It seems that the environment represents a braided fluvial stream environment passed offshore to tidal dominated migrating unidirectional dunes and sand waves. Waning currents in a relatively higher sea level stand led to the deposition of the trace fossil horizons.

1.3 Comparison

The WRP exhibits the best exposures of this, 1000 m, sandstone sequence in Jordan and the nearby countries. The sequence is not exposed throughout the eastern Mediterranean countries; e.g. Syria, Lebanon, Palestine, Sinai, Iraq and NE Arabia. However, it crosses the southern boundaries of Jordan and into Saudi Arabia. Outcrops of the same sandstone regime can be seen in NW Arabia southwards till Mada’en Saleh. Here, the sandstone sequence is much thinner and less complete. The exposures are deteriorated, possibly due to a lower cement/ grain ratio and consequently more erosional severity.

Another sandstone sequence of similar age; i.e. lower Paleozoic, can be seen in west central Oman, the Huqf Group. Again, the sequence here has been reduced to low lying hills, possibly due the severity of erosion and the roots of the pre existing sequence are now present. The exposures are not comparable to the majestic Wadi Rum area exposures.

Furthermore, the same sequence of sandstone, with similar age, crops partially is SW Egypt through southern Libya and Algeria. Again, in no one place of the North African Sahara, the whole sequence with its full magnitude can be seen exposed. In many parts of these countries, it is present in the deep subsurface or it has been eroded to provide the sands of the Sahara; e.g. north of the Auwainat in SW Egypt where these sandstones decrease in thickness until they disappear completely due to strong wind erosion of the Sahara.

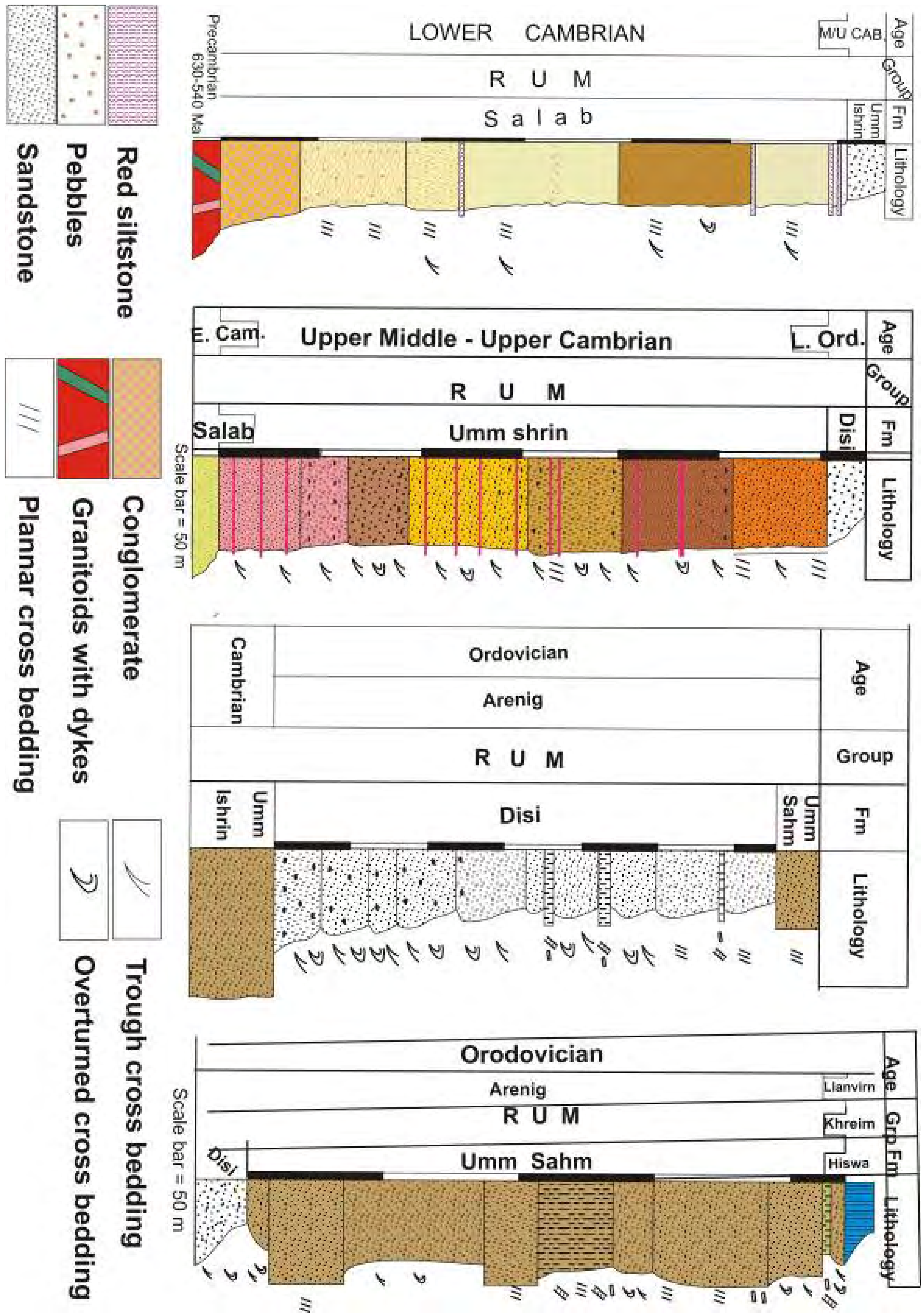

Fig. 1: Columnar section of the four formations making the sandstone sequence in Wadi Rum area. From left: Salab, Umm Ishrin, Disi, and Umm Saham Formations.

2. Structural Geology

It could be said with confidence that the present-day configuration of the Wadi Ram area is the manifestation of tectonics, especially faulting. Most of the wadis in the Ram area are oriented N-S after faults, while the while the continuous appearance of younger strata in SE direction is due to Tertiary tilting and uplift. No folding is seen in the Wadi Rum area. Following is a brief discussion of the tectonic elements in the WRP from older to younger.

2.1 Late Neoproterozoic uplift and erosion

After the culmination of the emplacement of the plutonic and volcanic rocks of the late Neoproterozoic at around 550-540 Ma, these rocks were uplifted possibly partly by the Najd Fault system. Strong and prolonged erosion led to the removal of a good part of the Precambrian basement to the degree that the top basement became peneplained. The peneplain surface marks the contact between the Precambrian basement and the Early Paleozoic sandstone sequence discussed above. Eroded material were deposited in intermontane basins further north producing thick sandstone sequence up to 2000m designated as Infacambrian in age. This sandstone sequence underlies the Early Paleozoic sequence in certain basins further north in Jordan, the Negev and Syria.

2.2 The Hercynian Orogeny

At around the middle Carboniferous, the whole Eastern Mediterranean was uplifted to form a broad geanticline with its apex being in north Sinai – Gaza and two basins: one to the SE in Tabuk area in northern Saudi Arabia and the other to the NE in northeastern Syria (Andrews, 1991). Erosion was severest at the geanticline apex were all pre Carboniferous Paleozoic strata were eroded. More and more Paleozoic strata were preserved in the SE direction, all pre Carboniferous deposits, Cambrian-Devonian, were preserved in the Tabuk Basin.

2.3 Tertiary Uplift

Since the end of Eocene, some 35 Ma ago, the interior Eastern Mediterranean including all Jordan, has been subject to an uplift process associated with preparations for the formation and opening of the Dead Sea Transform (DST). The resultant was the continuous uplift of the area and consequently the migration of the Tethys Ocean to approximately the present-day Mediterranean. Complete closure of the Tethys took place sometimes around the Middle Miocene, 15-17 Ma which is also the timing for the opening of the Gulf of Aden, the Red Sea and the DST. Since then, mountains on both sides of the DST have been rising and the floor of the DST subsiding. Both processes uplift and subsidence are still ongoing. Tertiary uplift has raised the WRP area and exposed it to the processes of weathering, erosion and denudation. The tectonics associated with the formation of the Dead Sea Transform, because of the northwards movement of the Arabian Plate, has led to various types of faulting seen in the WRP area. Both processes, uplift (and tectonics) and erosion, are ongoing and shaping the Wadi Rum area.

Rate of uplift is not the same throughout the western mountain chain in Jordan. It is certainly higher in south Jordan; i.e. the WRP, compared with north Jordan. Approximate rate of uplift in the WRP is around 60 m/1Ma, while it is half that number in the mountains near the capital Amman. This is possibly why erosion is cutting deeper in the south compared with north Jordan. South Jordan, including the WRP, has the highest mountains in the country.

Furthermore, the western mountain chain has been uplifted more rapidly compared with the E, SE and NE parts of the country; i.e. western Jordan (the mountain chain) is much higher than the Jordanian plateau in east. That is why younger strata are generally present further east. As a result, rate of Tertiary uplift increases both southwards and westwards. This conclusion is also true and apply to the whole length of the Red Sea-DST part of the Syrian-East African Rift system; e.g. mountains in NW Yemen are in excess of 3500 m compared with the low lying Rub Al-Khali desert further east.

Within the WRP and adjacent area, mountains are in excess of 1800 m while further southeast the plateau is around 900m. Due to this tilting, the top of the Precambrian basement is dipping towards the SE. That is why younger strata are cropping out down dip. The Precambrian basement is cropping out in the western parts of the WRP while at its eastern part the lower Ordovician Umm Sahm Formation can be seen.

2.4 Faulting

The faults in the WRP area and its surroundings can be divided into two groups

- Older or the NW-SE trending faults
- Younger or the N-S trending faults.

The geological map of the WRP is attached to show the various trends of the faults. The same map was part of the original report of nomination.

2.4.1 Northwest-southeast trending faults

Within the WRP and adjacent area, The NW fault trend is represented by a fault zone locally called the **Guwaira-Midawwara Fault zone**. This fault zone marks the northern boundary of the WRP. It starts in the NW from the northwestern corner of the WRP and runs in an SE direction for more than 100 km and then into the northern Saudi Arabia. It is not a single fault line but a fault zone more than 1 km wide at certain places. Faults of this trend are rather conspicuous along the northern side of the paved road just north of the WRP. In this vicinity, the down thrown blocks are to the left of the traveler to Wadi Rum. Thus, it is no difficult to see the red sandstones of Umm Ishrin Formation of the Middle Cambrian against the Precambrian basement; a down throw of more than 100 m.

The NW-SE fault system is tensional in nature. Consequently, the faults in this system are normal faults forming grabens and horsts along the fault zone length. Basalt dykes are characteristic of this fault trend. One of these dykes is present some 3 km north oft the WRP cutting through the Umm Ishrin Formation. An other occurrence of such dykes is to be found in Sahl Es Suwwan further southeast cutting through the Middle Ordovician Dubaydeb Formation. In another NW trending fault zone in the Dead Sea area, the Karak-Feiha Fault zone, the basalt was dated at 19-20 Ma, that is early Miocene. The Guwaira-Midawwara Fault was given a similar age. This type of faults seems to be contemporaneous with the formation of the DST.

2.4.2 North-south trending faults

The N-S fault trend is by far more abundant compared with the NW-SE fault trend. IT dominates the WRP and has major influence on the physiography and geomorphology of the Rum area. Almost all major wadis, within the WRP, are running N-S, and most probably originated some times in the past along the weak zones of this fault trend; e.g. Wadi Rum, Wadi Rouman, Wadi Marsad… etc.

The fault group is parallel to that of the Dead Sea Transform fault (DST) running along the eastern Wadi Araba further west. The DST is a plate boundary separating the Arabian Plate to east from the Sinai-Palestine microplate to the west. It formed during the Middle Miocene at around 15-17 Ma. It is a sinistral (left-lateral) strike slip where Jordan is moving north relative to Palestine with an annual rate around 5 mm/year. The total northward movement of Jordan since the formation of the DST is 107 km. The DST is typical of transforms making plate boundaries with earthquakes, pull-apart basins like the Dead Sea, pressure ridges, sage ponds, flower structures and the like. All that said about the DST, none of the N-S trending faults within the WRP has been reported of having a strike slip component except possibly the **Guwaira fault**.

The Guwaira Fault marks the western boundary of the WRP. It runs for more than 150 km within Jordan and continues into northern Saudi Arabia. Some 40 km left lateral movement has been reported on this fault.

However, the N-S faults are tensional faults or normal faults. The down thrown block is always to the E/SE. In each and every wadi; e.g. Wadi Rumman just west of Wadi Rum, the Paleozoic sandstones crop out at the western side of the wadi, while at the eastern side of the wadi the Precambrian granites are few tens of metres above the ground surface. This fault arrangement has produced tilted blocks between wadis with dip of the basement peneplain top being to the E/SE. That is why small springs are all the time found along the western sides of the wadis; e.g. Wadi Rum.

2.4.3 Other fault trends

There are minor faults trending E-W and NE-SW within the WRP area. However, they are of much less importance compared with the previous two trends.

Fig. 2 is the geological map of the WRP, reproduced here, to show the various types of fault trends. The NW-SE trend is not shown on the map because it is hust north of the WRP.

Fig. 2 Geological map of the WRP.

3. Paleoclimate

Paleoclimatic research in Jordan is rather limited and sporadic. Following is an overview of the paleoclimate works carried out in Jordan on sediments of the late Pleistocene in the various parts of the country. See a location map of the sites below.

Abboud (2000) reported a humid period at the **Holocene Optimum** 10-6 Ka in Wadi Muqat forming a small lake, **Burgu' Lake (Fig. 3),** followed by dry conditions after 5 Ka. Jericho, just to the NW of the Dead Sea, first appeared as a village in the Jordan Valley at around 8 ka or slightly earlier during the wetter Holocene Optimum (Kenyon, 1979; Neev and Emery, 1995). The wet conditions might be the reason behind the establishment of such agricultural village.

Huckriede and Wiesemann (1968) described a 1000-1800 km^2 fresh water lake in the Jafr basin in southern Jordan at 27-25 Ka, the **Jafr Lake.** They contend that this lake disappeared completely during the Last Glacial Maximum (LGM) at around 18 Ka. The Jafr Basin is around 100 km to the NE of the Wadi Rum Area. At present–day climate, the Jafr area receives < 50 mm/year of rain annually. The area is thus extremely arid and intensive and prolonged wet climate must have prevailed during the period of the Jafr Lake in order to produce and sustain such a large lake. It is reasonable to conclude also that all southern Jordan was wet during this period including the WRP, and such wet climate had affected the formation of wide wadis in the WRP like Wadi Rum.

Abboud (2000) also recorded one humid interval at 25 ka producing the **Burgu' Lake** and one dry interval at 21-15 ka in Wadi Muqat Basin in the extreme NE of the country where the Burgu' Lake disappeared.

Furthermore, Abed and Yaghan (2000) demonstrated the shrinkage of the large **Lisan Lake** in the Jordan Valley-Dead Sea to a sabkha during the Last Glacial Maximum (LGM). The Lisan Lake was 220 km long, 16-20 km wide and possibly 180 m deep occupying the Jordan Valley-Dead Sea Basin up till 22 Ka ago where it started shrinking. It shrinked into a sabkha and then disappeared completely between 22-16 Ka; i.e. during the coldest period of the last Glacial Maximum (LGM) A fresh water body, **Lake Damya** reoccupied the Jordan Valley around 14-12 ka (Abed, 1985) and disappeared during the colder period, the Youger Drayas at around 12=11 Ka.

The above three works on the Jafr Lake, Burgu' Lake, and Lisan Lake showed that the whole of the country was wet and warm around 25 Ka with much higher precipitation than present day, then became much drier and colder around the LGM at 18Ka.

A *Cardium* fresh to brackish lake, **the Mudawwara Lake**, was recorded in the Mudawwara area at around 135 ka (Marine Isotope Stages (MIS)–5a-e (Petit-Maire et.al, 2002; Yasin, 2001; Abed et.al., 2000) ; i.e. **Eemian stage**. The Mudawwara Lake is around 80 km SE of the WRP area. Its area is postulated to have been 1200 km^2 12 m deep at the Jordan-Saudi Arabia borders. The area is extremely dry and receives < 50 mm of rain annually. The Marine Isotope Stage (MIS) 5 was a warm and humid period. Precipitation must have been many time higher than present day precipitation to produce and sustain such a large fresh water lake in such arid area. The Mudawwara Lake is not far away from the WRP area, around 80 km (Fig. 3). Consequently, it is reasonable to say that the WRP had received intensive rain fall during the MIS5 some 135 Ka ago. Weathering and erosion by running water can be postulated to have formulated present-day wadis, like Wadi Rum, along the weak N-S fault planes discussed above.

Two *Cardium* horizons at the topmost Azraq formation in the eastern desert of Jordan are dated by the U/Th method at 331 ka and are assigned to interglacial to the warm and wet MIS 9. Fossil content, distribution and types as well as mineralogy indicate the presence of a single lake or possibly several smaller lakes of varying salinities from fresh to brackish occupying an area around 50 km wide and roughly 1300 km^2 within the Azraq Basin (Azraq-Umari area). At present, the area receives an average precipitation ranging 60-100 mm, and it is rather arid. Consequently, present-day Mediterranean rain cannot support the presence of lakes in such an arid environment. More intense Mediterranean cyclones during the warmer MIS 9 period might have carried more precipitable water than today. Because the study area is far from the Mediterranean, intensified Arabian monsoons or even Arabian-Indian monsoons may have penetrated further north and produced summer rain in the study area during the warmer MIS 9.

Turner and Makhlouf (2005) investigated a 652 ± 47 ka, 15 m thick friable sandstone horizon with abundant plant roots, beta calcrete and gypcrete from the Azraq Formation at the southern periphery of the Azraq Basin. They concluded that this sandstone correlates with MIS 17 at 659 ka, which was a wetter/warmer period.

The previous works, despite the fact that they are limited in number and far apart, indicate clearly a warmer/wetter climate, at least in parts of Jordan, during the late Pleistocene. More lakes were formed during the wetter/warmer times compared with the dry/cooler climates. This view is in general agreement with the interpreted paleoclimate of the North African Sahara (COHMAP, 1988; Yan and Petit-Maire, 1994; Gasse, 2000; Larrosoana, et al., 2003), Arabia (McClure, 1976; Al-Sayari and Zotl, 1978; Fleitmann et al., 2003) and SE Asia (Zhuo et al. 1998). There is ample research work in the North African Sahara indicating that the Sahara retreated more than 1000 km northwards to latitude 29-30^o producing a green savana in southern Libya, Algeria and nearby countries during the wet/warm Holocene Optimum 9.5-6 Ka ago. Similarly, Arabia was wetter during the Holocene Optimum and MIS5 up to latitude 27^o; i.e. just south of southern Jordan.

Recall that the Mudawwara Lake was at 29^o north. These wet/warm climates are interpreted to be due to the intensification of the monsoon rain during the warmer climate and where able to reach further north than present day monsoon rain.

Most probably, it was during these wet climates; e.g. Eemian and Holocene Optimum, that the wide wadis within the WRP were formulated via the erosion by running water. Also, long narrow canyons within the WRP, should have been produced by similar process. Present day climate cannot support the formation of such erosional features. It could also be added that the abundant groundwater, just east and SE of the WRP, had most probably accumulated during these wet periods.

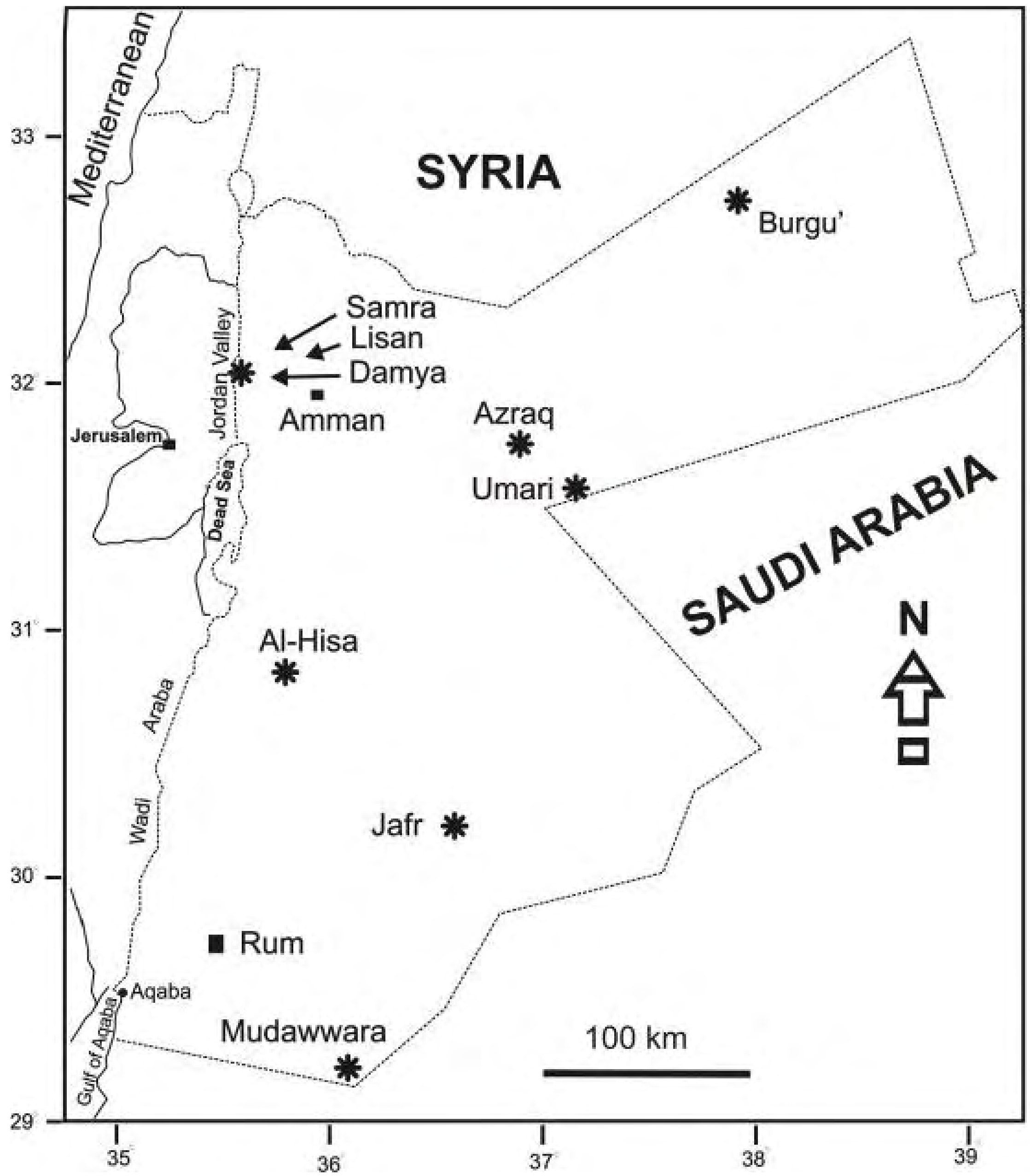

Fig. 3 Location map for paleolakes in Jordan during the late Pleistocene.

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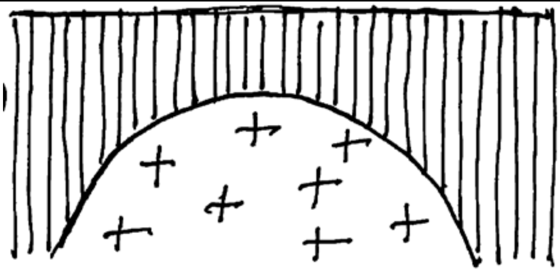
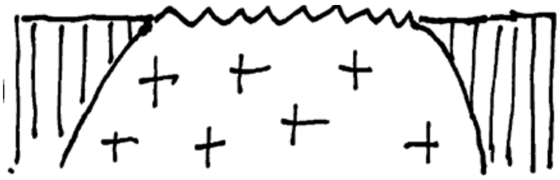
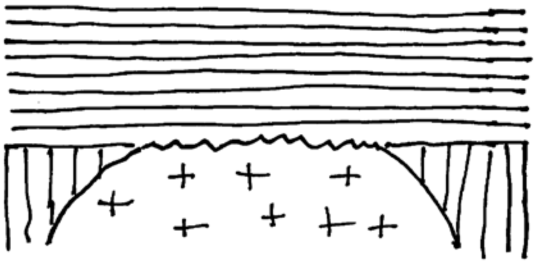
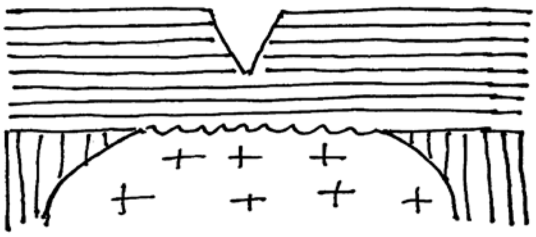
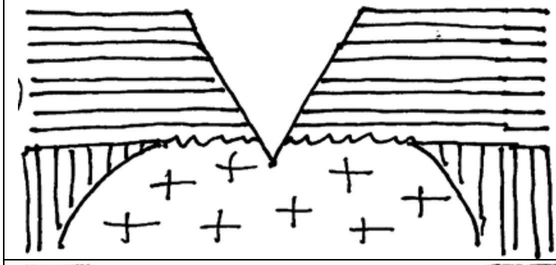
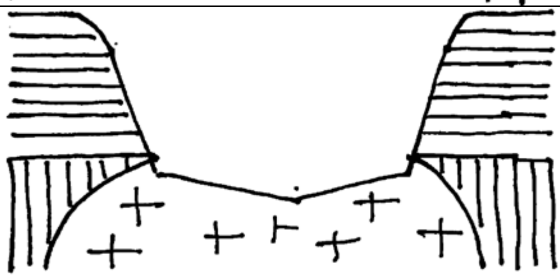
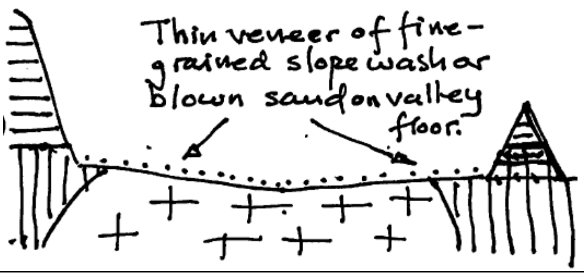
Wadi Rum Protected Area
Note on the General Models for Long-Term Landscape Evolution

	Ancient land surface, model 1, c.600my. Intrusion of granite pluton into ancient basement rocks.
	Ancient land surface, model 2. Erosion over millions of years to expose granite.
	Ancient land surface, model 3. Deposition of Wadi Rum sandstones covering ancient land surface (model 2).
	Uplift beginning 20-3 million years ago. Incision of drainage along structural lines/faults within sandstones.
	Continued uplift. Continued incision creating and isolating blocks (massifs), their shape and location dictated to be rectangular system of joints/faults in the sandstone.
	Uplift slows/ceases, only limited drainage incision linked to stable base level. Lateral erosion dominates, leaving low angle valley floors below near vertical cliffs.

	Uplift slow/ceased, very limited incision. Cliff retreat continues, widens valleys, where retreating cliffs meet, massifs are reduced to isolated inselbergs.

Following are explanations for differences in slopes, the existence of the characteristic forms, and the central role of weathering.

Model for the Evolution of Characteristic Slope Assemblages in Wadi Rum

The iconic landscape in Wadi Rum is one of steep-to-vertical sandstone cliffs separated by a sharp angle (break of slope) from low angle slopes. The slopes are mantled with a thin veneer of fine debris, and lead down gently to ephemeral stream channels. Commonly, these low angle, valley-floor slopes are covered by shallow deposits of blown sand. This sand can accumulate locally against the cliffs as 'climbing dunes'.

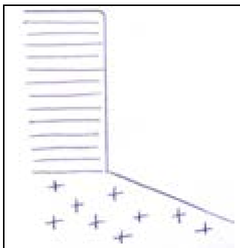
There are places in Wadi Rum where the cliffs are partially masked by accumulations of coarse debris from earlier cliff collapse. Indications are, however, that these accumulations do not persist for long in the context of overall cliff retreat, and breakdown into sand that can either be blown away or washed over the gentle, valley floor slopes.

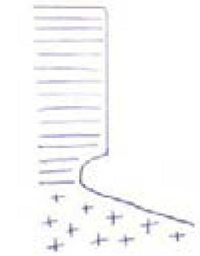
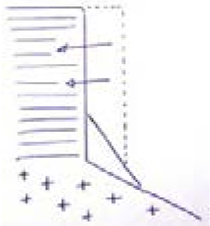
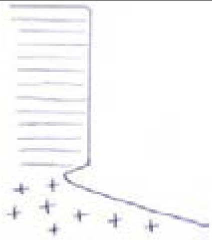
In some locations, debris persists, and in these situations, the gradual accumulation of debris 'consumes' the cliff by burying it and effectively halts cliff retreat and landscape development. Crucial, therefore, to the creations of the iconic cliff/valley floor landscape, is the maintenance of the sharp break of slope between the two elements. This requires a combination of two factors: the concentrations of weathering and erosion at the base of the cliffs; and the relatively rapid removal of collapsed debris – most probably linked to a rapid reduction to sand-sized and finer material that can be either blown away, or require only a low-angle slope to allow it to be washed away by periodic overland flow.

Conditions Associated with Cliff Retreat and Maintenance of Break of Slope between Cliff and Valley Floor

Model A

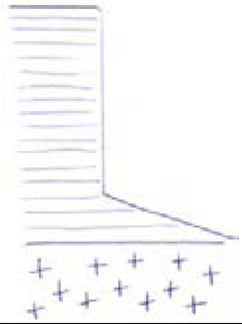
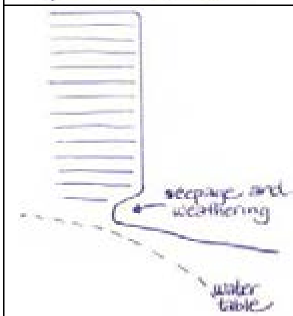
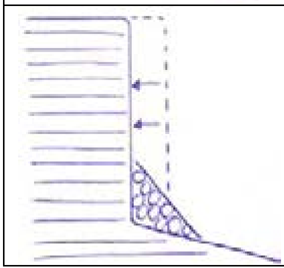
Coincidence of boundary with lithological boundary between granite and overlying sandstone.

	Break of slope located at boundary between granite and overlying sandstone.

	Weathering and erosion concentrated at boundary, probably linked to seepage of water soaking through sandstone and encountering less permeable granite.
	Undermining leads to collapse and retreat of cliff and accumulation of slope foot debris.
	Slope foot debris weathers quickly to sand – a characteristic of sandstones <u>and</u> granites - fine material removed (washed/blown away) and undermining begins again.

Model B

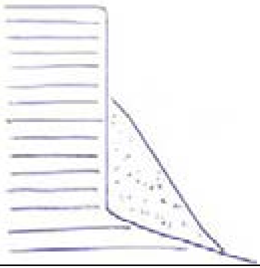
Break of slope located within sandstone formations.

	Break of slope located within sandstone above boundary between sandstone and underlying granite.
	Cliff is undermined by a concentration of weathering and erosion at the foot of the cliff where it intersects the water table, which supplies the moisture required for weathering. Forms characteristic caves or 'tafoni' formed mainly by salt weathering.
	Cliff sections undermined by weathering leaving characteristic arcuate tailing scars and accumulations of coarse debris in cliff foot zone.

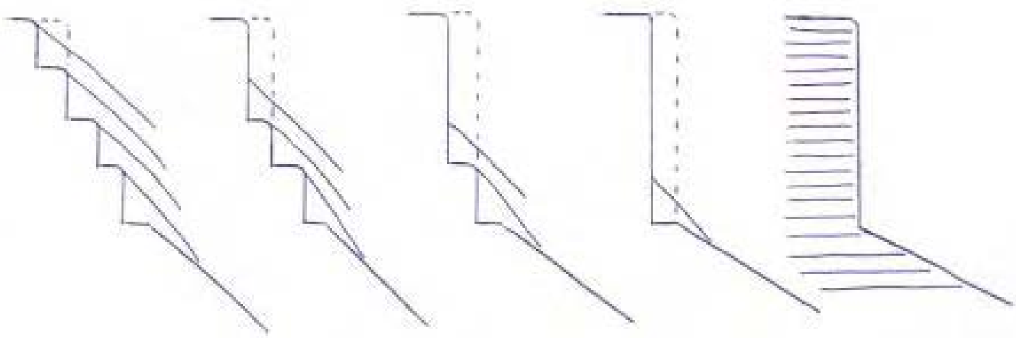
	Coarse debris breaks down into sand that is washed or blown away, allowing cliff-foot weathering and undermining to re-commence.

Variants on the General Model of Cliff Retreat

Model C

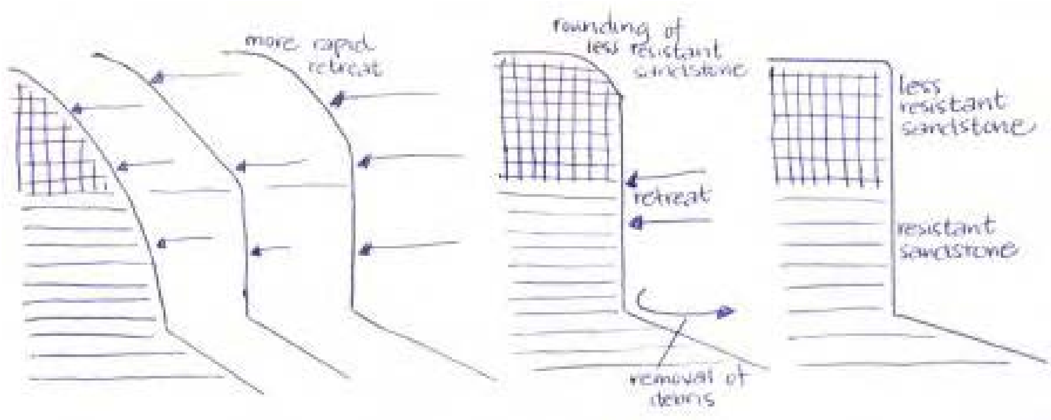
	Cliffs effectively stabilized and "fossilized" by accumulations of blown sand as "climbing" dunes.

Model D



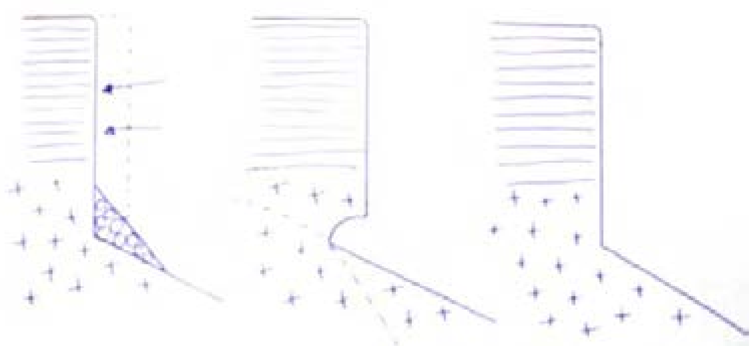
Cliffs retreat by undermining at the boundary between cliff and debris slope. BUT accumulated debris is NOT removed (impeded basal removal, possibly linked to slow weathering of debris or shelter from erosion processes, e.g. wind). As the reduced cliff continues to retreat, it buries preceding falls with more debris, the cliff gets gradually smaller and is replaced by a high angle debris slope of coarse material. Slope angle is proportionate to debris size, the finer the debris, the gentler the slope and vice versa.

Model E



Two sandstones overly each other - the overlying one is weaker and weathers more rapidly, and the lower, resistant sandstone retreats leaving a vertical cliff. BUT, above it, because the less-resistant sandstone retreats more rapidly, it creates a convex slope which, over time replaces the vertical cliff below, to produce rounded, residual hills.

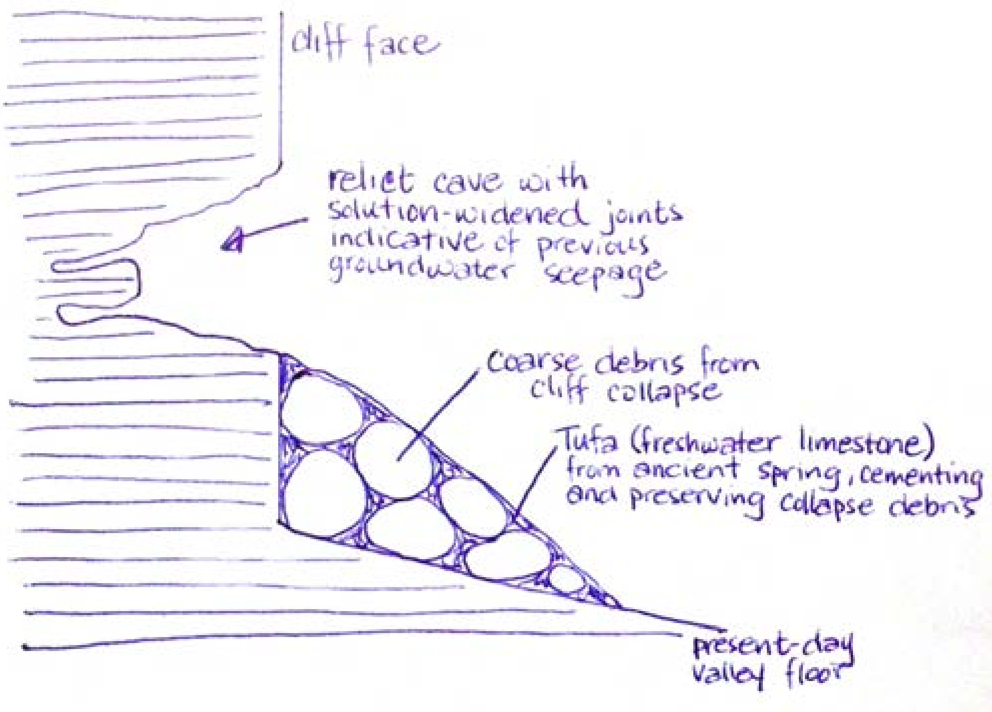
Model F



The break of slope is within the underlying granite. In these cases retreat is controlled by the cliff intersecting the water table and this appears to override any structural control.

Because the positioning of the break of slope is controlled so strongly by where it intersects the water table (or most likely the capillary fringe above the water table), it is clear that slope development will be strongly influenced by any fluctuation in the water table. Evidence of such fluctuations can be found in relict karstic caves within the cliffs above the level of the current valley floor. These once supported considerable flows of water, as evidenced by tufa-cemented debris below them. This might also suggest that both cliff retreat and valley floor incision may have been more rapid during past periods of greater moisture availability, for example, the last climatic optimism.

Typical Fossil Spring-Sapped Cave in Cliff above Present-Day Valley Floor


cliff face
relict cave with solution-widened joints indicative of previous groundwater seepage
coarse debris from cliff collapse
Tufa (freshwater limestone) from ancient spring, cementing and preserving collapse debris
present-day valley floor