# GEOMORPHOLOGY AND BIOGEOGRAPHY OF TROPICAL DESERTS

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**Summary**

Geomorphology of Tropical Deserts is driven by the dry climatic condition of the environment. The heat provided by the sun reaches the surface and creates a high temperature in days, but at night the temperature falls. This cycle creates the conditions conducive to the physical weathering that predominates in the tropical deserts. Aeolian processes commands the shaping of surfaces, moving sediments provided by the weathering. These conditions occur in a specific area of the Earth near the sub-tropical

areas. The fauna and vegetation of Tropical Deserts are adapted to the extreme environmental conditions. Adaptive processes were developed to suit their supplies of water and food.

## 1. Introduction

Deserts ecosystems located in tropical regions are environment of extremes, with lack of moisture and generally synonymous with arid regions. They are one of the hottest and driest areas of the planet, with no or sporadic rainfall. These conditions are due to some different conditions as continentality, topography and subtropical high pressure cells influence. These kinds of deserts are located in south and north hemispheres, especially between 5 and 30 degrees of latitude.

The tropical desert is an environment of extremes: it is the driest and hottest place on earth. Rainfall is sporadic and in some years no measurable precipitation falls at all. The terribly dry conditions of the deserts are due to the year-round influence of subtropical high pressure and continentality.
In tropical areas the heat enhances evaporation and the dryness conditions of the areas with little precipitation. Rain also occurs in a few events and quickly the moisture is absorbed by the soil or evaporated. These climatic conditions do not allow the geochemical processes of weathering to happen and most of the rock transformations are due to physical processes of contraction and expansion with the break of rocks in fragments. In this case, most of the desert surface is occupied by fragmented rocks, outcrop rocks or sand. Lack of vegetation, bare rock or sand, mountains and canyons, mesas or buttes, dunes, basins and playas, washes and arroyos, alluvial fans and generally angular topography are all deserts characteristics.

Geomorphic processes performed by the wind are called eolian processes, or aeolian after the Greek god of the wind Aeolus. In tropical deserts the work of wind shapes the Earth's surface. Though dominating dry climates, eolian processes are also effective in semi-arid, sub-humid or humid regions as well.

## 2. Tropical Deserts

### 2.1. Geographical Distribution

Tropical Deserts are typically found in continental interiors of the tropics with extensions to the subtropical areas and on the leeside of mountains. Such deserts are also found in cool coastal regions where cold water upwells along a coast, stabilizing the air and preventing moisture formation like that near Chile’s coast. Vast deserts cover parts of Africa – The Kalahari, The Sahara, extensive areas in the Middle East from Saudi Arabia to Iran, part of south Asia in Pakistan and western India. Tropical deserts are found also in Baja California and interior Mexico in North America. In South America this kind of deserts occurs in north of Chile and south parts of Bolivia and Peru, The Atacama. (Figure 1 – Table 1)

| **Desert’s Name** | **Area ($km^2$)** | **Country/Countries** |
|---|---|---|

| | | |
|---|---|---|
| Sahara Desert | 8 600 000 | Egypt, Libya, Chad, Mauritania, Morocco, Algeria. |
| Arabian Desert | 2 331 000 | Saudi Arabia, Jordan, Iraq, Iran, Kuwait, Qatar, United Arab Emirates, Oman and Yemen. |
| Great Victoria Desert | 647 000 | Australia |
| Chihuahuan Desert | 450 000 | Mexico and United States |
| Great Sandy Desert | 400 000 | Australia |
| Kalahari Desert | 260 000 | Botswana, Namibia and South Africa |
| Syrian Desert | 260 000 | Syria, Jordan and Iraq |
| Gibson Desert | 155 000 | Australia |
| Simpson Desert | 145 000 | Australia |
| Atacama Desert | 140 000 | Chile and Peru |
| Namib Desert | 135 000 | Namibia |

Table 1. Major tropical desert by area.
Source: http://en.wikipedia.org/wiki/List_of_deserts_by_area.

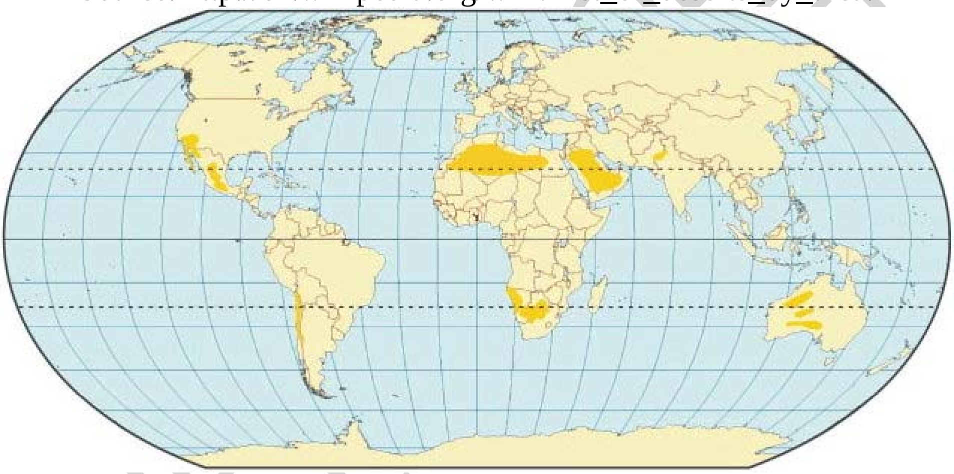

Figure 1. Location of tropical deserts.

## 2.2. Controlling Factors

The most important controlling factor for the tropical desert climate is the year-round presence of subtropical high pressure with hot, dry descending air cells called Hadley Cells, the Sahara, Arabian, Sonora and northern Atacama Desert are of this type. The effect of descending air from subtropical high adiabatically warms causing the air to dry out and inhibit condensation. Also, if the distance from moisture sources increases, aridity will also rise. Situation in the mountainous areas which provokes rain shadow conditions also promotes dry conditions. Cool coastal deserts are found in areas along coasts where cold water is upwelling them.

Deserts occur in specific latitudes (5-35° north and south of the equator) because of the general thermodynamics of our planet. Solar radiation hits the earth with highest intensity near the equator. Because the earth's axis is tilted 3.5° with respect to the plane of its orbit, during part of the year the zone of maximum solar interception shifts northwards, towards the Tropic of Cancer, and during part of the year it moves southwards, towards the Tropic of Capricorn. Thus, the warm tropics form a belt around the equator from latitude 3° north to latitude 3° south called Intertropical Convergence Zone, where the tropical heat generates rising, unstable air.

When the air moves up, it condenses the moisture evaporated from seas and forests at warm tropical areas. In this movement from the equator to the tropics at high altitudes, the air cools again and starts descending towards the midlatitudes both north and south. The air masses become extremely dry in this movement because of the loss of their moisture during their tropical ascent. So, the mid-latitude arid fringes that run alongside the tropical belts have a more stable atmosphere than the equatorial areas.

### 2.3. Distinguishing Characteristics

#### 2.3.1. Temperature

Tropical deserts present the highest average annual temperature of any climate on the planet. These high temperatures are motivated by the highest percentage of sunshine of any climate caused by the high sun angles throughout the year. The lowest temperature never reaches below 18$^{o}$C and many places have consecutive average monthly temperatures in the mid 30 degrees Celsius. The high energy input during the day and large loss at night results in an extremely large daily temperature range. During days the temperatures at low elevation inland deserts can reach 40-50$^{o}$C and the daily difference could reach 50$^{o}$C.

The tropical desert sky remains cloud-free due to the subsiding air of dominant high pressure resulting in large amounts of insolation. The high insolation days caused by the cloudless sky not only causes an intensive amount of energy on the land surface, but also lets much heat out at night.

#### 2.3.2. Precipitation

The precipitation is very irregular in the tropical deserts. Deserts located at low latitude have an average precipitation less than 250 mm.y$^{-1}$. Some desert have years without rains, because they are located far from the ocean and in areas over intense action of high pressure cells, a condition that combines and creates a very dry environmental condition.

The tropical desert climate is influenced by upper air stability and subsidence which is the result of the presence of the subtropical high pressure zone. Relative humidity is normally low, averaging 10 to 30 percent in interior locations. Precipitation is very low in quantity and very infrequent in distribution, both temporally and spatially. Temperature varies greatly both diurnally and annually. The highest average monthly temperatures on the Earth are found in the tropical desert. They range between 29 to 35 degrees Celsius. Winter monthly temperatures can be 15 to 25 degrees cooler than summer temperatures. This climate also has extreme diurnal ranges of temperature. The average diurnal range is from 14 to 25 degrees Celsius. (Table 2).

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**Bibliography**

Allan, J.A., Warren, A., Tolba, M., and Allan, T. (1993). Deserts: The Encroaching Wilderness (A World Conservation Atlas). Oxford University Press, Oxford [This book aims to present the state of the world's deserts, their peoples and their wildlife and also provides a basis for action.]

AUSTRALIA'S DESERTS, DESERT WILDLIFE OF AUSTRALIA. Dr Chris Pavey, Research Scientist, and Catherine Nano, Botanist, Biodiversity Conservation Unit, Northern Territory Parks and Wildlife Service, Alice Springs. Visited at http://www.abs.gov.au/ausstats/abs@.nsf/ Previousproducts [This article is about the environmental conditions of Australia's deserts]

Bagnold, R.A. – The Physics of Blown Sand and Desert Dunes. Methuen, London 1954. (This classical book provides an overview about sand dunes and aeolian processes)

Brook, B.W., and. Bowman, D.M.J.S. (2004).The uncertain blitzkrieg of Pleistocene megafauna. Journal of Biogeography 31: 517–523 [This research using meta-analysis of empirical data and population modeling presents plausible scenarios for the cause of late Pleistocene global mammal extinctions]

Cartledge V. A., Withers,P. C., McMaster K. A., Thompson G. G., and Bradshaw S. D. - Water balance of field-excavated aestivating Australian desert frogs, the cocoon-forming Neobatrachus aquilonius and the non-cocooning Notaden nichollsi (Amphibia:Myobatrachidae) J. Exp. Biol., September 1, 2006; 209(17): 3309 - 3321. [This article shows na overview about the adaptive strategies of frogs in the Australian Desert]

Chesson, P., Gebauer, R.L.E., Schwinning, S., Huntly, N., Wiegand, K., Ernest, M.S.K, Sher, A., Novoplansky, A., and Weltzin, J.F. (2004). Resource pulses, species interactions, and diversity maintenance in arid and semi-arid environments. Oecologia 141: 36– 53 [This article presents the strong control from the sparse and variable precipitation over the physiological characteristics, and species composition of the desert biota]

Cooke, R., A. Warren, and A. Goudie, 1993. Desert Geomorphology. London: University College Press. [This book provides an interesting approach about processes and landforms that occurs in Deserts]

Cloudsley-Thompson, J.L. (1996). Biotic Interactions in Arid Lands. Springer, Berlin–Heidelberg [This book is a basic account of the synecology of deserts. It covers a wide range of topics that have been studied extensively in other biomes, but not yet in arid lands]

Davis, S.J.M. (2005). Why domesticate food animals? Some zoo-archaeological evidence from the Levant. Journal of Archaeological Science 3 (9): 1408–1416. [this article presents changes in the animal exploitation in desert areas in the Palaeolithic and Neolithic times]

Ezcurra, E., Montaña, C., and Arizaga, S. (1991). Architecture, light interception, and distribution of Larrea species in the Monte Desert, Argentina. Ecology 7 (1): 23–34. [This paper analyzes the correlation between leaf orientation and the environmental conditions that prevail within the bio-geographic range of each of the four South American Larrea species]

Goudie, A.S. (2002) Great Warm Deserts of the World: landscape and evolution. Oxford University Press. [This book present na overview about warm desert and their evolution]

Holmgren, M., Scheffer, M., Ezcurra, E., Gutiérrez, J.R., and Mohren, G.M.J. (2001). El Niño effects on the dynamics of terrestrial ecosystems. Trends in Ecology & Evolution 16(2): 59–11 [this paper presents new studies showing the El Nino has major implications for the functioning of different ecosystems, ranging from deserts to tropical rain forests]

Loik, M.E., Breshears, D.D., Lauenroth, W.K., and Belnap, J. (2004). A multi-scale perspective of water pulses in dryland ecosystems: climatology and ecohydrology of the western USA. Oecologia 141: 69– 81 [This paper present a research about dryland ecosystems, in special the timing and magnitude of precipitation pulses drive many key ecological processes, notably soil water availability for plants and soil microbiota]

Louw, G.N., and Seely, M.K. (1982). Ecology of Desert Organisms. Longman, London [The emphasis of this book is on the adaptive responses of organisms to desert conditions]

Mabbutt, J.A. (1977). Desert Landforms. MIT Press, Cambridge, Massachusetts. [This book presents an overview of desert landforms and their processes]

McGinnies, W.G., Goldman, B.J., and Paylore, P. (eds.) (1977). Deserts of the World. University of Arizona Press, Tucson. [Massive standard work on deserts with research into their physical and biological environments. ]

Mulongoy, K.J., and Chape, S. (2004). Protected Areas and Biodiversity: An Overview of Key Issues. UNEP-WCMC Biodiversity Series No. 1, Nairobi, Kenya. [This publication synthesizes key aspects in the development of protected areas, the level of international commitment and the relationship of protected areas to sustainable development, and reviews critical issues related to their effectiveness.]

Olson, D.M., Dinerstein, E., Wikramanayake, E.D., Burgess, N.D.,Powell, G.V.N., Underwood, E.C., D'Amico, J.A., Itoua, I., Strand,H.E., Morrison, J.C., Loucks, C.J., Allnutt, T.F., Ricketts, T.H., Kura,Y., Lamoreux, J.F., Wettengel, W.W., Hedao, P., and Kassem, K.R.(2001). Terrestrial ecoregions of the world: a new map of life on Earth. BioScience 51(11): 933–938 (maps available online at: http://www.worldwildlife.org/science/ecoregions/terrestrial.cfm). [This study presents the characteristics of the eco-regions of the world.]

Pianka, E.R. (1986). Ecology and Natural History of Desert Lizards: Analysis of the Ecological Niche and Community Structure. Princeton University Press, Princeton, N.J. [This paper examine patterns of co-existence for three species of scincid lizards (*Sphenops sepsoides*, *Scincus scincus*, and *Chalcides ocellatus*) in the simple sand dune habitat of North Sinai]

Pipes, R. (1998). Hot Deserts (World Habitats). Raintree, New York Ricciuti, E.R. (1996). Desert (Biomes of the World). Benchmark Books, New York [This book show that the world's deserts have high levels of endemism and harbour rare and unique life forms, a fact that makes them ecologically fragile and highly vulnerable to biological extinction.]

Ritter, Michael E. The Physical Environment: an Introduction to Physical Geography.2006. Date visited. http://www.uwsp.edu/geo/faculty/ritter/geog101/textbook/title_page.html. [This book provides an overview about physical environment]

Robichaux, R.H. (ed.) (1999). Ecology of Sonoran Desert Plants and Plant Communities. University of Arizona Press, Tucson [The book covers a wide variety of topics about the Sonoran Desert]

Schmidt-Nielsen, K. (1964). Desert Animals: Physiological Problems of Heat and Water. Clarendon Press. Oxford. [This book provides an overview about desert animals]

Selby, M.J. – Earth's Changing Surface. An Introduction to Geomorphology. Clarendon Press. Oxford. New York. [This book provides an overview about geomorphological systems and process]

Shmida, A. (1985). Biogeography of Desert Flora. In Ecosystems of the World. Vol.12. Hot Deserts and Arid Shrublands (eds. M. Evenari, I. Noy Meir and D. Goodall) pp. 23–75. Elsevier, Amsterdam. [This chapter present na overview about vegetation and biogeography of desert areas]

Strahler, A., Strahler, Arthur – Physical Geography. Science And systems of the Human Environment. John Wiley & Sons, Inc. New York. [A classical introductory book to physical Geography]

Thornthwaite, C.W. (1948). An approach toward a rational classification of climate. Geographical Review 38: 55–94. [This classical paper presents a system of climatic classification]

UNEP - Global Deserts Outlook - www.unep.org/geo/GDOutlook/ [presents a panorama of the environmental status of the world's deserts]

wikipedia - List of deserts by area - http://en.wikipedia.org/wiki/List_of_deserts_by_area in 24 May 2007. [An electronic encyclopedia which present a list of deserts ]

Woodward Susan L - Biomes of Earth, Terrestrial, Aquatic, and Human-Dominated, Greenwood Press. 2003. [Provides a thorough and accessible description of the climate, plant and animal life, origins and human impacts, and history of the scientific exploration of every major biome in the world.]

**Biographical Sketches**

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