

# Landscape - Functional Valorisation and Sustainable Development in the Valley of the Volcanoes in Peru

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## Abstract

The Valley of Volcanoes is located in the Andes of south Peru. Together with the Colca Canyon which it joins, it is an object of research of Polish scientists whose goal is to protect the area by designating the Colca Canyon and the Valley of Volcanoes National Park. The valley is approximately 90 km long and despite its location at high altitude it is relatively well economically developed. The aim of the paper is to present an analysis of the state and structure of land use, including factors and barriers of development and landscape-functional values. Individual elements of the landscape of natural and anthropogenic origin have been identified including division into harmonious landscape resources e.g. viewpoints and picturesque routes, landscape dominants and existing threats to the landscape by landscape degrading objects. Landscape-functional zones of various attractiveness and geodiversity were designated. Principles of environment management were established in each zone, objects and protection goals were determined and their threats defined. The results will be applied to a plan of protection of the future national park.

**Keywords:** structure of land use, development barriers, landscape-functional zones, the Valley of the Volcanoes, Peru

## Introduction

The Valley of the Volcanoes and the Colca Canyon have been the object of research since 2003 carried on by a team from several scientific centres and coordinated by Prof. Andrzej Paulo from AGH University of Science and Technology in Cracow. The goal of the project is to create scientific foundations for a national park that would be designated in the area [1]. The field investigations have been almost completed and the current results were presented at the Polish-Peruvian scientific conference (Arequipa, 15-16.07.2010) "Geology of the Colca and the Valley of Volcanoes regions – a bridge between nature and man".

The authors of the article intend to prove that the Valley of Volcanoes, despite representing broad range of altitude-climate zones forms common linear landscape-

functional structure. Environmental values in the structure need various forms of protection depending on their importance and sensibility.

## Characteristics of the Research Area

The research area is located in the Western Cordillera of Central Andes. The area belongs to the Arequipa Department, the Castilla Province and it lies within the following communes (from the north): Orcopampa Chilcaymarca, Chachas, Andagua, Ayo and partly Choco.

The Valley of Volcanoes is approximately 90 km long, 3-8 km wide in the northern part 4-6 km in central and 1-3 km wide in the southern part. In its northern part, where the bottom of the valley is situated at the altitude of 3800 m a.s.l. there is mining town Orcopampa. Further, it

descends gently down and in the vicinity of Andagua (central part, 3659 m a.s.l.) it turns into a system of steep morphological thresholds. The outlet of the valley into the Colca Canyon is located at the altitude of 1360 m a.s.l. (southern part). Recent lavas fill up the Valley of Volcanoes between Misahuanca and Ayo along the distance of 60 km forming a cover (Fig. 1). The remaining valley fill are flat lying sediments: gravels and colluvia or sands.

The Valley of Volcanoes is a typical example of a tectonic graben. The northern part of the graben runs meridionally and is significantly older. It can be proved by occurrence of well-developed soil on the slopes. Rock walls appear in the central part. The eastern part of the graben above Chachas Lake is still active. It is similar to the outlet of the valley into the Colca Canyon where longitudinal, vertical faults cutting recent lavas of the Andahua Group can be observed.

Volcanic forms of the Andahua Group are almost erosionally intact, prominent, resembling primary landscape. Lava flows predominate, lava domes and pyroclastic cones. The lava covers total area of 221 km<sup>2</sup>. There are 40 lava domes and 17 pyroclastic cones on the bottom of the Valley [2].

The lava fields are related to at least three periods of volcanic activity. The oldest lavas are weathered, surface mostly smooth, covered with vegetation and often turned into fields. There is gentle relief on the second generation of the lavas, initial soil, sometimes covered with grass, cactuses and bushes. The surface of the youngest lava is uneven, the lava flows slopes are steep, unstable and almost inaccessible. Vegetation has little chance to root there.

The forms of the two latter generations can be distinguished in the field. The largest part of the area is covered by the youngest lavas (Holocene) beginning south of Andagua and extending down to the Colca Canyon. A slightly older lava field (Pleistocene – Holocene) occurs north of Andagua. It is the vicinity of the abandoned antimony mine Santa Rosa where Puca Mauras volcano dominates (4181 m a.s.l.). The lavas are over 100 m thick there and they outpoured from five lava domes (Fig.1).

## Research Methodology

The works on landscape-functional valorisation were carried out in three stages:

I<sup>st</sup> included field and desk works enabling to identify each form of land management and usage, ecological zones, existing and planned objects and protected areas of nature, landscape and cultural heritage, harmonious landscape resources e.g. viewpoints and picturesque routes, landscape dominants and existing threats to the landscape by landscape degrading objects. The results of this work were marked on a geoenvironmental map of the investigated area and allowed the making classification of the landscape based on its resources and the degree of anthropogenisation (Fig. 1).

II<sup>nd</sup> involved an assessment of environmental components and identified the areas in terms of their usefulness

and usability for various economic and social needs. The result was the designation of landscape-functional zones.

III<sup>rd</sup> involved division of the area into zones of various landscape attractiveness differing in rigors of protection (Fig. 2).

## Results

Estimating the spatial structure of the landscapes of the Valley of the Volcanoes and the surrounding area in more specific terms, we can distinguish the following four types of landscapes:

- The bottom of the intermountain graben filled with fluvial and limnic sediments, peat bogs or lava flows, used as pastures or terraced fields fed by irrigation ditches.
- Mountain slopes forming the verges of the intermountain graben, passing into very steep rock walls, with well-developed talus which is covered in the north by soil.
- Altiplano, which directly adjoins the Valley of Volcanoes in the north, represents a semi-desert landscape with gentle hills and lakes.
- The Cordilleras, where mountain peaks with permanent snow cover occur (the massif of Coropuna volcano 6425 m a.s.l.).

Planned national park covers approximately 350 km<sup>2</sup> in the southern part of the valley. Its boundaries at the

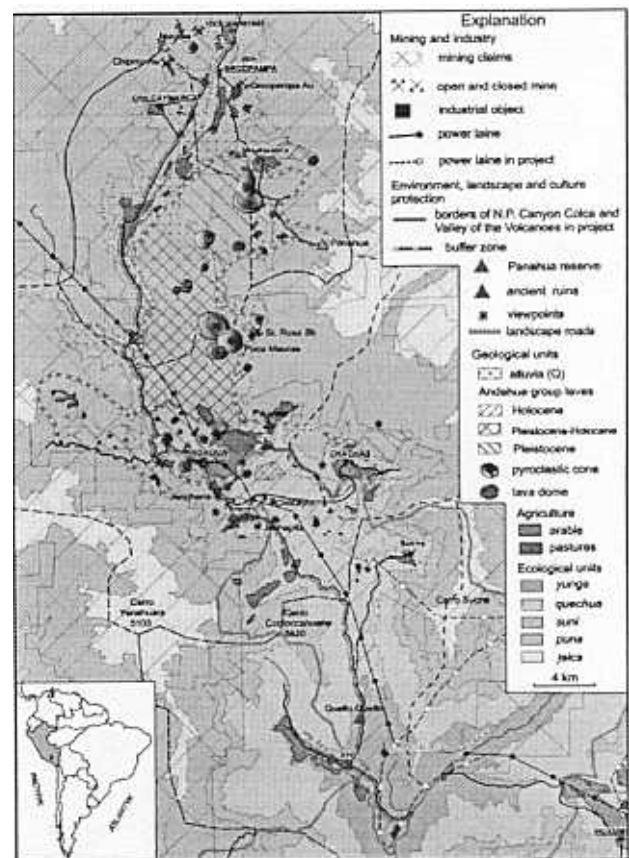


Fig. 1. Geoenvironmental maps of the Valley of the Volcanoes.

bottom of the Valley of the Volcanoes and extends along Canyon of the Rio Colca. Its boundaries at the bottom of the valley have been proposed basing on the range of the youngest generation of the Andahua Group. This is an area of the highest scientific, educational and landscape values. Within its boundaries the following zones applied national parks of Peru have been designated [3]: strict and partial protection, special use and recreation.

A buffer zone, covering the area of 187 km<sup>2</sup> has been designated to the north of the valley. It covers lavas of older generation (Pleistocene-Holocene). Inside and outside the buffer zone within the Valley of the Volcanoes there are areas of the following potential (Table 1, Fig. 2): a) highly productive, b) settlements, c) mineral deposits and d) nature and culture protection.

### The Highly Productive Areas

Access to water, suitable climate and topography are the conditions necessary for development of agriculture in the Andes. The lavas near Andagua were significantly weathered and fertile soils have formed on them. They are currently developed as a system of terraced fields with irrigation ditches. The Andagua River located in the catchment area of the Rio Colca is the main watercourse in the province of Castilla and the source of water for agricultural development in the Valley. Abundantly supplied, the river forms small pools and bogs in its upper part. In the

central part of the valley to the south of Chachas Lake Andagua River disappears beneath lava flows for some 15 km and abundantly flows out into Mamacocha Lake.

The climate of the Valley of Volcanoes is characterized by distinct vertical zoning, which is reflected in land use in agriculture (Table 1). Favourable conditions for agricultural crops exist in the vicinity of the village Andagua (some 7 km<sup>2</sup>) and north of the Chachas Lake. Smaller arable fields occur in the lateral valleys Sucna and Soporo. Exceptional vegetables are cultivated in Ayo. At the altitude of about 2000 meters a.s.l. not only maize, potatoes, but also guava, papaya, peach, bananas, citrus fruits and even grapes are growing. Farming conditions are Water supply is not stable, as may be proved by the abandoned settlements of Quello Quello north of Ayo. Agriculture is not mechanized and so far seems to have no impact on other components of the environment. Above the altitude of 3600 m a.s.l. livestock farming based on herds of alpacas and llamas occurs in areas where water is available. Large pastures spread west and north of Andagua, practically up to Orcopampa.

### Settlements

The largest town in the Valley of the Volcanoes is a mining town Orcopampa with population reaching six thousand. Buenaventura Mining Company, which obtained concession on mining and exploration in Orcopampa in 1960, has developed the basic residential and communication infrastructure and also medical and educational facilities in the town. Andagua is the second settlement where about one thousand people live. Other settlements: Chilcaymarca, Chachas, Ayo are even smaller. All inhabited places are located near water resources. Larger settlements have water pipeline systems, sewage systems and electricity supply. There are also few hotels offering rather low standard of services.

The road network consists of one main unpaved road that runs along the bottom of the Valley. The few branches are practically available only for 4WD vehicles. A new road connecting Ayo and Huambo together with the bridge over the Rio Colca is under construction. It would shorten by half the road distance to the capital of the Arequipa Department.

### Mineral Deposits

The gold mine Chipmo, built close to the historic silver and gold mine Orcopampa and the ore treatment plant, is currently the most important industrial facility in the region. The exploitation is carried on at the depth of 600 m below the surface [1]. In 2010, approximately 0.5 million tons of ore were mined, which gave 9 tons of Au [4]. The number of exploration claims on both sides of the Valley Volcanoes grows every year. Among successful Shila, Poracota and Parihuana should be mentioned. The positive effects of exploration, and good economic results of the mines attract new investors and employees, resulting in economic development of the region [1]. In the

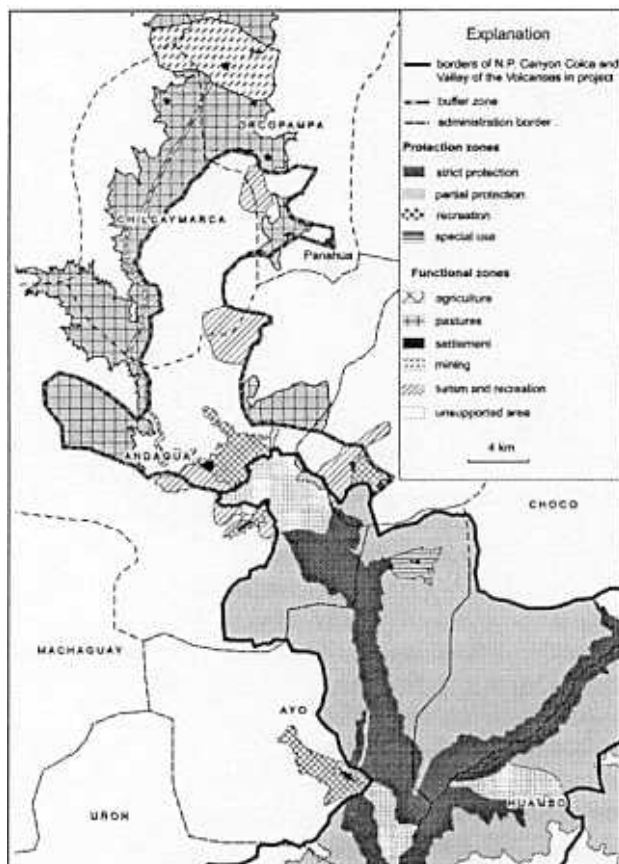


Fig. 2. Landscape-functional zones in the Valley of the Volcanoes.

Table 1. Functional-landscape valorization of the Valley of the Volcanoes.

Ecological units [8]	Economic potential	Protection areas	Evaluation of environment, landscape, education	Conflicts
<i>Yunga</i> (500-2300 m a.s.l.) South part of Valley has a desert character, surface of lavas is water and plants less, same species of cacti and sec bushes.	a) productive area, d) nature and culture protection,	Strict conservation for mainly area	High: lavas and faults (Holocene), active morphological processes, few types of landscape, otter habitat	Power line, planed changing of location and high of the transmission tower, road in planed
<i>Quechua</i> (2300-3500 m a.s.l.) Central and south part of Valley, were temperate to sec conditions of climate are dominate, good predispositions for agriculture. Are observed same trees (eucalyptus).	a) productive area, b) settlements, d) nature and culture protection,	Strict and partial conservation for mainly area, buffer zone with cultivated areas	High: volcanoes (Holocene), lavas and faults, active morphological processes, diversity of landscape	Power line, planed changing of location and high of the transmission tower.
<i>Suni</i> (3500-4000 m a.s.l.) North part of Valley. The temperate cold climate are dominate, is the border of extent of agriculture. Are observed tuft of grass <i>ichu</i> and <i>chudo</i> .	a) productive area, b) settlements, c) mineral deposits	Partial conservation, buffer zone and communal reserve	Middle: volcanoes and lavas (Pleistocene-Holocene) few types of landscape	Planed changing of high of the transmission tower,
<i>Puna</i> (4000-4800 m a.s.l.), Surroundings area of Valley. Typical in vegetation cover are species of strong grass, herbs and pastures.	c) mineral deposits	Partial conservation for small area,	Small	No exists

closest vicinity of the protected area near the Mauras volcano, there is also a small quarry supplying rock materials used for road constructions and closed mines Santa Rosa and Shila.

### Nature and Culture Protection

A unique geological position and exposure are the main advantage of the Colca Canyon and the Valley of Volcanoes, which result in large lithological, stratigraphic and tectonic variety. Active geological processes such as earthquakes and faulting, erosion and mass movements and, above all, various forms of volcanic edifices can be observed there. Accumulation of different, dwarf volcanic forms on relatively small area makes it exceptional in that part of the Andes. Those are extremely attractive pyroclastic cones [5], lava domes and lava flows [2, 6], which add greatly to the geodiversity of the planned national park. The pyroclastic cones are relatively small 100-250 meters high. Some cones have craters broken by lava, which allows to enter there study their interior. The surface of lava flows is built of sharp-edged lava of "aá" type and deeper of block lava. Research works show that the last volcanic activity took place in the Valley about 370 years ago [7].

The edges of Valley of Volcanoes graben are tectonically active. Structure of faults and folds can be observed in many exposures. Several transverse faults cut the valley where congealed lava formed cascades [2].

A group of Panahua ice/waterfalls, south of Orcopampa has been covered by protection as a landscape reserve. Other interesting waterfalls are located near Andagua.

There are ruins of ancient settlements and tombs in the Valley eg. Pajareta, Pumajallo, Antaymarca, Soporó, Quello Quello and old Ayo. Most of the objects have not been inventoried and investigated yet. Before they become open for tourists, detailed archaeological investigations and necessary reconstruction works should be carried out.

### Conclusions

Considering the civilization progress, there is a need for concrete actions towards the rational management of animate and inanimate nature. The concept of shaping the development of the Valley of Volcanoes, resulting from the usage and exploitation of resources and environment values, should be preceded by determination of their value and suitability to perform specific functions in regional economy.

The method of determining specific zones of land use, nature and culture protection presented in the paper, was applied successfully to heterogeneous region of the Valley of the Volcanoes. The thesis that the early exclusion of areas with high geodiversity from investment pressure will enable optimal land use in other areas. Environmental resources usage: agriculture, pastures, tourism and recreation, exploration and mining of mineral deposits follow the boundaries of geological formations and ecological zones, which occur in the Valley of the Volcanoes. The mining centre Orcopampa which attracts investors and craftsmen and drives economic development is dominating in the region.

Protection of geodiversity resources and designation of the Colca Canyon and the Valley of Volcanoes National Park depends entirely on the abilities of state administration and regional and the awareness of local communities. Investments which are to be carried out in the Valley of Volcanoes i.e. increase of the height of transmission towers, construction of a bridge and a road at the mouth of the Colca Canyon were the subject of intensive protests in Arequipa. In the authors' opinion, both projects need detailed analysis of their influence on the environment and public consultations. Their proposed location will cause irreparable damage of the landscape of the most valuable part of the Valley of Volcanoes and the Colca Canyon. The proposed changes in the spatial structure (designation of the National Park and the buffer zone) would enhance the chance for balanced development of the designated zones based on tourism and recreation and to protect areas with high geodiversity, great natural beauty and still little-known cultural and natural values.

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