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The geoglyphs of Palpa, Peru: documentation, analysis, and interpretation

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3. Geoglyph research in the Nasca region

In this section, previous research of the Nasca geoglyphs is summarized and critically reviewed in order to define a baseline for the present study. Starting from the premise that a precise documentation is a prerequisite for any analysis and interpretation, both fields of work will be treated here in separate subsections. For both documentation and analysis/interpretation, starting points for investigating the Palpa geoglyphs are identified, and this researcher´s approach is shown to be built on previous research and additional premises. The research in Palpa will then be described in the following sections.

3.1 Geoglyph documentation

3.1.1 Previous research

Anyone who intends to study the Nasca geoglyphs will soon discover that finding suitable data about them is a difficult task. This is somewhat surprising, considering the amount of available literature on the topic. However, as Anthony Aveni, who directed an important research project on the Nasca *pampa* in the 1980s, rightly states,

> "[. . .] much that has been written about the Nazca lines is too long on speculation and too short on documentation." (Aveni ed. 1990: iii)

Indeed, descriptive data on specific geoglyphs is rarely presented in the literature (*e. g.* Ravines et al. 1995), and photos as well as sketches of geoglyphs are often shown without information about their precise location. The situation is somewhat less problematic with regard to maps of the geoglyphs, because a fair number are available. However, the quality of most of the maps is far below professional standards for the documentation of archaeological features.

The maps can be grouped into five categories:

- Overview maps that show the general location of geoglyphs in a large area, but not the precise shape and location of specific geoglyphs [8]
- Maps that show some, but usually not all geoglyphs of a certain area. They are based on terrestrial measurements of the orientation and length, but not the precise shape of selected geoglyphs (Kern/Reiche 1974: figs. 4, 37; Reiche 1993: *passim*)
- Sketch maps of geoglyph sites usually based on aerial images and/or observations made in the field that often show the basic components of geoglyph complexes, their relation to each other and to their environment, but neither their precise shape nor their exact location [9]
- Maps that show as completely as possible the geoglyphs existing in a certain area. They are based on a photogrammetric analysis of aerial images with the completeness of the map constrained by the scale of the images used [10]
- Compilations of maps that combine data from several of the above mentioned sources (Reiche 1993: encarte 9.1; Reinhard 1996: hojas 2–6) or for which no sources are detailed (Lumbreras 2000: *passim*).

As the overview indicates, all available maps of geoglyphs have certain deficiencies with regard to their accuracy or completeness. This becomes especially evident in the case of the northern part of the Nasca *pampa* for which several maps from different sources are available. These maps show differences not only in scale, coordinate system and graphic rendition, but also in content [11]. Their suitability for archaeological research is therefore limited. Many other parts of

8 Kern/Reiche 1974: figs. 1–3; Aveni ed. 1990: fig. II.1b; Reiche 1993: 568–569; Reinhard 1996: hoja 1; Lumbreras 2000: 142.

9 Silverman 1990b: figs. 11–17; Aveni 1990b: fig. II.3; Lumbreras 2000: *passim*; Mejía 2002: fig. /P8:3200(1)/.

10 Hawkins 1974: figs. 3–6; Instituto Geográfico Nacional 1993; Nikitzki 1993.

11 Some of these maps are in error. For example, on Nikitzki's map some well known figural geoglyphs that are actually located outside the area covered by the map are depicted in arbitrary places among correctly mapped geoglyphs (Nikitzki 1993).

the Nasca drainage are not covered by archaeological maps. Thus, the state of documentation of the geoglyphs is insufficient. A review of the techniques employed to map the geoglyphs will illustrate the reasons for this unsatisfactory situation.

Terrestrial measurements

The first one to map geoglyphs on the Nasca *pampa* was Maria Reiche. Starting in the late 1940s, she used measuring tape and a compass for surveying (Reiche 1993). Later, she also measured arcs of lines with paper templates (Reiche 1993: fig. 11.5). Her main tool, however, was a theodolite, which she used for mapping the outlines of figural geoglyphs (Reiche 1993: 467 ff). Theodolites have furthermore been used by Reiche and others to determine the azimuth orientation of straight features such as lines, straight sections of figures, or borders of trapezoids[12]. On the resulting maps geoglyphs surveyed this way are usually depicted as standardized lines without information about their precise width, length, or shape. It is generally possible to measure the location, shape and size of a geoglyph using a theodolite (*e. g.* Reindel et al. 1999: figs. 11–13). However, the amount of work is prohibitive when one considers the number of existing geoglyphs. This is why the use of theodolites has largely been restricted to determining the orientation of the geoglyphs.

Aerial photography

Aerial imaging is a common tool for archaeological research on the Peruvian coast. Due to the lack of vegetation in the coastal desert, archaeological remains lay open on the surface and can be recognized to a certain degree in aerial images (depending on image scale). The aerial photographic service of the Peruvian air force (*Servicio Aerofotográfico Nacional*, SAN, Lima) has systematically produced high quality aerial photos of many parts of the country since the 1940s. All coastal valleys have been photographed several times at different image scales during the last decades.

The images were usually taken for cadastral, agricultural, or planning purposes. Therefore, often only inhabited or economically developed zones are covered such as the irrigated and settled valley floors. Desert zones that are not economically developed are usually covered by high altitude flights resulting in small scale pictures. The images can be purchased at reasonable prices from the SAN or IGN (*Instituto Geográfico Nacional*) offices in Lima.

Since SAN images are easily available and affordable for archaeological projects, many researchers use them as a natural starting point for their investigations. In the Nasca region, the SAN was furthermore commissioned on several occasions to perform special flights to take photos of geoglyph concentrations on the Nasca *pampa* (*e. g.* Reiche 1976: 21; Hawkins 1974). Many well known and often published photographs of Nasca geoglyphs have been taken during these flights. Thus, SAN aerial images are a widely used tool in Nasca archaeology. Archaeological sites are located, and sometimes classified, based on what can be discerned in the SAN photos. Often, sketch maps are produced with the aid of these images, and they are used in publications to illustrate archaeological contexts.

However, in spite of these efforts SAN images do not cover all areas with geoglyphs, nor at a scale that enables the recognition of the narrow lines. Therefore, additional aerial images were taken by some projects. In 1984, within the framework of Anthony Aveni's project (see section 3.2.1), an unmanned, tethered balloon to which a small format camera was attached was used. The aim was to take low altitude, vertical images of several line centers. However, only one picture of a line center in the southern part of the *pampa* could be taken due to technical problems (Johnson et al. 1990: 278, fig. VII.2, 4; Aveni 2000a: 156–159, figs. 40, 41). Thus, the contribution of balloon photography to the documentation of geoglyphs is so far quite limited[13].

In Aveni's project, after balloon photography had largely failed to deliver the desired results, it was decided to rent a small aircraft to take a series of vertical aerial images of a part of the Nasca *pampa* with an aerial camera (Johnson et al. 1990: 278). The image flight covered the northern bank of Río Nasca well into the *pampa*. The resulting images had a scale of 1:24,000 and were combined into a photomosaic (Aveni ed. 1990: supplement). However, the film supply, originally calculated only for a limited number of shots to complement the balloon flights, was not enough to cover the whole *pampa*, to achieve a greater scale, or to allow a general overlap of the images that would have

[12] Reiche 1976; Hawkins 1974; Aveni 1990b.

[13] Balloon photography has also been used outside the Nasca area by Rodríguez to document a figural geoglyph in the Chillón valley (Rodríguez 1999: figs. 7, 8, 16).

enabled full stereo processing (Gerald Johnson, personal communication 2003). Thus, while being helpful for general orientation in the southern section of the Nasca *pampa*, the photomosaic allows only the largest geoglyphs to be discerned.

Photogrammetry

Aerial photography is normally used for orientation and illustration. Some researchers, however, have analyzed aerial images using photogrammetric means. Photogrammetry allows accurate 3D measurements of objects based on two or more images of them. Its application is therefore a qualitative step further compared to the simple sketch maps produced from single aerial images.

In the Nasca area, there are three published geoglyph maps developed using photogrammetric methods (see above). All of them cover the same area: the northern edge of the Nasca *pampa* along the left bank of Río Ingenio, *i. e.* the area with the largest concentration of geoglyphs and with most biomorphic figures. British-American astronomer Gerald Hawkins was the first to apply photogrammetry to Nasca archaeology. His map is the only one for which specific information on the database is given:

> "We decided to extend the stereographic and standard photogrammetric method used at Stonehenge and Callanish in Britain. This method provides contours above mean sea level and a rapid and accurate mapping of all surface features. We cooperated with the Geophysical Institute of Peru and the Servicio Aerofotográfico Nacional (SAN) of the Peruvian Air Force. On August 1, 1968, SAN obtained 30 overlapping, high-resolution photographs of the area. These were used to make a ground plan to the scale of 1:2000, so that 10 centimeters on the chart represented 200 meters on the ground." (Hawkins 1974: 125)

Unfortunately, no information as to the scale of the aerial images is given in Hawkins' report. The map is published at a reduced scale, and the geoglyphs are depicted as dashed lines which seriously affects interpretation of the map. According to Hawkins, all geoglyphs wider than 30 cm are depicted, but the narrowest lines encountered in the field had a width of 10 cm (Hawkins 1974: 119, 125). Thus, Hawkins' map is an important step forward in the documentation of the geoglyphs, but it still has certain deficiencies.

After Hawkins' efforts, two other maps were elaborated with photogrammetric methods (Instituto Geográfico Nacional 1993; Nikitzki 1993). They were published without accompanying notes, and no information about the photos for either of them is given. It seems possible that both maps were based on the same set of aerial images used by Hawkins. However, the three maps have different scales, very different graphic styles, and show discrepancies in their content, *i. e.* the geoglyphs depicted on them. It is not clear if archaeologists contributed their expertise to the making of either of the three maps.

3.1.2 Review of documentation methodology and research approach

Considering how fragile the geoglyphs are today, their documentation is utterly important in terms of their long-term preservation. Moreover, without good documentation any attempt at cultural historical analysis or interpretation will be problematical. Hence, any new study of the geoglyphs has necessarily to start with reliable and accurate documentation.

The maps that are available have considerable deficiencies because the focus of most research projects has thus far been on explaining the geoglyphs rather than on recording them. And as mentioned previously, applied methods of geoglyph recording have not proven efficient enough. In order to overcome these shortcomings, it is necessary to take advantage of the diverse tools offered by modern mapping methodology.

Topographical surveys are today usually based on remote sensing techniques. In remote sensing, information about an object – in this case, the geoglyphs on the earth's surface – is obtained by sensors that capture electromagnetic radiation emitted or reflected by the object, *e. g.* sunlight or radar rays. Different types of sensors allow the geometry, composition, temperature, use, etc. of the earth's surface or objects upon it to be recorded. To document the Nasca geoglyphs, optical airborne or spaceborne sensors are possible candidates since they provide information about the location, size, and shape of the geoglyphs, as well as the surrounding terrain.

Satellite remote sensing

So far, data obtained by spaceborne sensors has not been used for documenting the Nasca geoglyphs, because high resolution satellite imagery has become available only recently. The level of

Satellite / Sensor	Swath width	Spectral Band Pan	Spatial Resolution	Website
COSMOS KVR-1000	40.0 km	0.51-0.76 µm	2.0 m	www.sovinformsputnik.com
EROS-A	13.5 km	0.50-0.90 µm	1.8 m	www.imagesatintl.com
IKONOS	11.3 km	0.45-0.90 µm	1.0 m	www.spaceimaging.com
ORBVIEW-3	8.0 km	0.45-0.90 µm	1.0 m	www.orbimage.com
QUICKBIRD-2	16.5 km	0.45-0.90 µm	0.61 m	www.digitalglobe.com

Table 2. Satellites and sensors that provide high resolution panchromatic imagery (as of May 2004).

detail visible in an image depends on its spatial resolution, which can be expressed in pixel size. A resolution of 1 m pixel size means that a square of 1 m edgelength on the ground has a unique color, or gray value, in the digital image. In Palpa where all geoglyphs are to be recorded, imagery is needed that allows detection of even the narrowest lines, which have a width of approximately 10 cm. To show such geoglyphs with enough detail to map them accurately the pixel size should at least come close to their minimal width. Ideally, it should be even smaller.

Such high spatial resolution is so far not commercially available from spaceborne sensors, even though over the past few decades image resolution has increased considerably. When the last well documented fieldwork on the Nasca *pampa* was carried out in 1984 under the direction of Anthony Aveni, the best available images were those taken by NASA's analog Large Format Camera (LFC) mounted on the Space Shuttle during mission STS-41G (Doyle 1985). Depending on orbit, film, and atmospheric conditions, spatial resolutions from approximately 5 to 20 m were achieved. Furthermore, images taken by the Landsat 4/5 Thematic Mapper sensor with a spatial resolution of 30 m were available at that time (Lillesand et al. 2004: tables 6.1, 6.2).

In 1997, when the first photo flight over Palpa and Nasca was performed within the framework of SLSA's project with airborne sensors, the best available resolution of civil spaceborne sensors was 5.8 m which was provided by the Indian IRS-1C and D satellites (Lillesand et al. 2004: table 6.8). By then, the Russian government had made available selected images taken by the analog KVR-1000 camera mounted on several satellites of the military COSMOS series (Lillesand et al. 2004: 463). These panchromatic images offer a spatial resolution of 2 m, but cover mainly parts of Europe, Asia, and North America.

At the time of writing (2004), panchromatic sensors mounted on satellites launched by private companies capture imagery with a spatial resolution that comes closer to the useful range for geoglyph mapping yet is still not high enough. The recently launched EROS-A satellite provides digital imagery with a spatial resolution of 1.8 m. The IKONOS 2 as well as ORBVIEW 3 satellites deliver a spatial resolution of 1 m, while QUICKBIRD 2 even achieves 0.61 m pixel size (Lillesand et al. 2004: table 6.14). As of May 2004, the Nasca *pampa* was covered by four QUICKBIRD images and several series of IKONOS images, whereas no high resolution EROS A or ORBVIEW images have thus far been taken over that area. For Palpa, only one QUICKBIRD image covering the eastern half of the area of investigation is currently available[14].

In the years to come, new civil sensors with a panchromatic resolution of 0.5-0.4 m are likely to be launched[15]. It is to assume that in the military realm the best available spatial resolution is already much higher, probably in the centimeter range. However, due to legal and other constraints (Fritz 1999), such imagery is unlikely to become available to civil users in the foreseeable future[16].

Table 2 gives an overview of the characteristics of several sensors that currently offer the highest available spatial resolution in panchromatic imagery. The actual availability of images over specific areas can be checked via the company websites.

[14] Information based on survey of online image databases of the respective companies conducted on May 13, 2004. For up-to-date results see company websites as given in table 2.

[15] See press releases "DigitalGlobe unveils plans for next-generation spacecraft constellation" (March 23, 2004) at www.digitalglobe.com and "Space Imaging reacts to new White House remote-sensing policy" (May 13, 2003) at www.spaceimaging.com (accessed May 13, 2004).

[16] See also fact sheet on "U.S. commercial remote sensing policy" (April 25, 2003), available as PDF at www.licensing.noaa.gov (accessed May 13, 2004).

All in all, imagery from spaceborne sensors is currently not available at a spatial resolution that would allow a detailed recording of the Nasca geoglyphs including the narrowest lines which was the aim of the Nasca-Palpa Project. Nevertheless, if the focus is put on other aspects then data provided by satellite sensors can be helpful in many ways. For example, a partial geoglyph mapping may be accomplished using satellite images. Virtually all areal geoglyphs, like trapezoids and rectangles, as well as the wider lines (yet not the famous biomorph figures) are visible in existing IKONOS and QUICKBIRD images. Mapping these larger geoglyphs would provide a basic documentation which for many geoglyph sites is not yet available. Satellite images can be ordered in georeferenced form and used for mapping in 2D or even stereoscopically in 3D if stereo images are available. Considering the need for conservation and protection of the geoglyphs today, such an approach would already be helpful in many cases, and the resulting maps could be used as starting point for further studies.

The generation of digital terrain models (DTMs) or maps of large areas, *e. g.* the whole Nasca basin, is another task for which satellite sensors offer suitable data. In Peru, governmental agencies like SAN or IGN use combinations of images taken by airborne and spaceborne sensors to produce and update maps and digital terrain models of the whole country, though so far only at small scales. Other sources offer DTM data based on spaceborne sensor imagery as well. As an example, stereo imagery acquired by NASA's ASTER sensor mounted on the TERRA satellite (Lillesand et al. 2004: 481 ff, table 6.21) is used to generate DTMs with up to 7 m horizontal accuracy. Stereoscopic imagery with different resolution from other sensors (SPOT, JERS-1, ADEOS, IKONOS etc.) is likewise suitable for DTM generation.

Another source for height information of the earth's surface is synthetic aperture radar (SAR) interferometry. The phase difference of microwaves emitted and received by two radar sensors arranged along a known baseline allows the elevation of the point on the surface from which the waves are reflected to be calculated. A large-scale application of this method to generate DTMs was NASA's Shuttle Radar Topography Mission (SRTM) flown in 2000. During this mission, approximately 80% of the surface of the earth was recorded by radar interferometry. SRTM data enables the generation of DTMs with an accuracy of better than 20 m (horizontal) and 16 m (vertical) (Lillesand et al. 2004: 712 ff).

From 1997 to 1999, SAR interferometry has been applied to detect geomorphological change in the desert surface of the Nasca *pampa* (Lefort et al. 2003, 2004). Although the results show that a good part of the vast plain is relatively stable and does not show any change, erosion channels coming out of the foothills of the Andes and crossing the *pampa* are clearly visible. The monitoring of geoglyph sites and especially the identification of areas where natural erosion is likely to occur is important for efficient geoglyph preservation (cp. Lumbreras 2000).

Aerial photogrammetry

The many benefits of satellite imagery notwithstanding, aerial images are still the best choice if an accurate and complete 3D mapping of all geoglyphs of a given area is needed. They potentially offer a spatial resolution high enough to identify even the narrowest lines. Depending on flight height, the camera used, and the area to be covered, images at a scale of up to 1 : 2,500 can easily be obtained during standard photo flights. The larger the scale the more images are required to cover a given area.

3D object extraction and DTM generation require the taking of overlapping images in order to obtain stereopairs suitable for a photogrammetric analysis. In order to map the Nasca geoglyphs in the Palpa area, it was decided to focus on an analytical photogrammetric analysis of large scale aerial images. Photogrammetry has seldom been applied to Nasca archaeology, and the results are rather mixed. This, however, seems largely because the scale of the images used did not allow a complete mapping that would have included the many narrow lines. Furthermore, the mapping efforts seem to have been accomplished largely without archaeological expertise.

Thus, the potential of modern photogrammetry for geoglyph recording should not be judged from previous efforts alone. Rather, a survey of recent applications in cultural heritage recording shows that modern analytical and/or digital photogrammetry is a powerful tool if applied correctly. In Europe, Asia, and Australia, photogrammetry has successfully made its way into every-day archaeological research. In New World archaeology, however, it has rarely been employed. Some recent exceptions include the documentation of Maya architecture in Honduras and Mexico (Gray/Boardman 2002; Desmond/Bryan 2003), the recording of monumental *adobe* architecture on the Peruvian north coast (Reindel 1993; Sauerbier et al. 2004), and the documentation of terraces and other structures in the northern Peruvian Andes (Capra et al. 2002).

Photogrammetry, like laser scanning, allows for high accuracy 3D recording at relatively low cost. In the following part, the potential, the procedures, and the requirements of photogrammetry are briefly outlined. Detailed introductions about the principles of photogrammetry are available elsewhere[17].

The American Society for Photogrammetry and Remote Sensing (ASPRS) defines photogrammetry as follows:

> "Photogrammetry is the art, science, and technology of obtaining reliable information about physical objects and the environment, through processes of recording, measuring and interpreting images and patterns of electromagnetic radiant energy and other phenomena." (www.asprs.org/asprs/society/about.html, accessed May 27, 2004)

In other words, photogrammetry allows the acquisition of metric information about the size, shape, and position of a given object – *i. e.* data that allows the geometric reconstruction of that object – by measurements of the object in images, thus eliminating the need to measure the object itself. In this sense, photogrammetry is a subfield of remote sensing, where information about an object is obtained by sensors that do not touch the object itself, but rather record electromagnetic radiation emitted by the object. In photogrammetry, optical sensors like cameras are used to capture lightwaves reflected by the object from which an image is generated. This accomplished,

> "[t]he fundamental task of photogrammetry is to rigorously establish the geometric relationship between the image and the object as it existed at the time of the imaging event. Once the relationship is correctly recovered, one can then derive information about the object strictly from its imagery." (Mikhail et al. 2001: 1)

Photogrammetry allows a wide range of objects to be surveyed and measured from microscopic particles to whole planets (see Luhmann 2002 for an overview of recent research). In the case of cultural heritage, the advantages of measuring in images instead of at the actual object become readily evident:

- Taking images of an object is usually faster and easier than physically measuring it
- In the case of delicate objects, measuring in images helps avoiding potential damage caused by surveying activities
- An object can be measured even if it has disappeared or considerably changed since the images were taken.

Photogrammetric measurements in images basically require suitable images, information about the camera, and 3D survey control data:

- Images: From a single image of an object, only 2D data can be easily derived. For measurements that aim at the recovery of metric 3D data, at least two different images of the object are usually needed. Similar to the way human vision works, two views of an object from slightly different viewpoints allow the object to be seen in 3D. This basic procedure of photogrammetry is called stereoscopic viewing. In order to record an object in 3D, a series of images has to be taken in a way that every part of the object is covered by at least two adjoining images. The overlapping areas of the images allow not only stereo viewing, but also 3D measurements.
- Camera: The way an image of a real-world object is generated depends on technical characteristics of the camera like focal length, lenses used, etc. These parameters determine the distortion of the image when compared to the object. The technical characteristics of the camera can be calibrated by taking photos of a test field of points whose spatial positions have been measured.
- Control data: To enable the correct scaling and positioning of recorded objects, the precise location of certain points, or the precise length of certain ranges visible in the images needs to be established by independent measurements.

Thus, images and control data have to be acquired at the object itself while camera calibration data can either be obtained in the office or simultaneously during the process of image acquisition (self calibration). The time necessary to acquire data is usually much shorter than data processing and analysis which has to be carried out in the office.

[17] Mikhail et al. 2001; Lerma 2002; Luhmann 2003; Kraus 2004.

Once the camera has been calibrated the images can be oriented relatively to each other. Using control data they can then be oriented absolutely in space. In the overlapping area of two adjoining and oriented images (stereopairs) 3D measurements can be carried out. The results of the measurements are then digitally recorded. Based on this data, the geometry of the object can be reconstructed in a virtual computer environment. If photorealism is needed, texture is generated from the images and draped over the geometric model. Different products can be derived from the model, like maps and plans. The digital 3D data is especially well suited to be integrated on a GIS platform where it can not only be managed and edited, but also analyzed as for inherent spatial relations between its components.

If these prerequisites are complied with modern aerial photogrammetry seems a powerful tool to accurately record the Nasca geoglyphs in 3D. The geoglyphs are distributed over wide, largely flat terrain and lay open on a surface not covered by vegetation. These are ideal conditions for aerial photogrammetry since the geoglyphs can be completely recorded by taking vertical aerial images organized in parallel strips with a calibrated aerial camera mounted on an aircraft flying at low altitude. Today control data can easily be obtained by determining the absolute position of certain points clearly identifiable in the aerial images with the global positioning system (GPS). That way, the photogrammetric fieldwork can be reduced to a photo flight and some GPS measurements. The actual mapping and drawing of the geoglyphs can then be done in the office using photogrammetric hardware and software.

Complementary archaeological fieldwork

The great potential of photogrammetry notwithstanding, it cannot substitute archaeological fieldwork. The geoglyphs were made, used, and perceived on the ground and should also be studied on the ground. Ground level contact with the geoglyphs allows them to be correctly identified and mapped using aerial images. And, verification of the resulting maps in the field allows an assessment of the quality of the mapping procedure. Also certain aspects of the documentation of the geoglyphs cannot be captured by image based recording. For example, cultural remains like ceramics or lithics, stratigraphic relationships between geoglyphs, and alterations of geoglyphs are important aspects that can hardly be documented in images alone. Thus, photogrammetric recording should be combined with thorough archaeological recording. Since the actual mapping of the geoglyphs can be done in the office fieldwork can be dedicated entirely to the description of geoglyphs and any associated cultural remains which is an important advantage.

Geographic Information System (GIS)

To store, manage, analyze, and visualize hybrid data in an efficient and sustainable way geographic information systems (GIS) are especially suitable. GIS has become an important tool in archaeological research since the 1990s[18]. This is due to the capability of GIS to make use of the inherent spatial component of archaeological data, as stressed by the authors of the recently published first textbook on archaeological applications of GIS:

> "Artefacts, features, structures and sites, whether monument complexes, chance finds of individual objects, scatters of ploughsoil material or rigorously excavated structural and artefactual remains, are all found *somewhere*. As well as the position of the feature or artefact itself there may also be a series of *relationships* between the locations of features and artefacts, revealed by significant patterns and arrangements relative to other features and things." (Wheatley/Gillings 2002: 3; emphasis in original)

A strong point of GIS is that it allows the placing of archaeological features and finds in a topographic and environmental context, and to systematically analyze patterns and interdependencies between different types of data. This ability is partially responsible for the increased focus on landscape archaeology in recent years[19]. However, GIS is a useful tool not only on a regional scale, but also at the site level for managing and analyzing data resulting from geophysical prospection or excavation (Neubauer 2004).

A geographic information system is mainly composed of tools for data storage, analysis, and visualization (cp. Wheatley/Gillings 2002: fig. 1.2). Its core is a database management system (DBMS) in which archaeological as well as other data is stored (Ryan 2004). A careful structuring of the database is decisive for effi-

[18] Baena et al. 1997; Kvamme 1999; Gourad 1999.

[19] Gramsch 1996; Gillings et al. eds. 1999; Anschuetz et al. 2001.

cient data retrieval, editing, and querying. A second element of a GIS is the one which is often regarded as the GIS itself: it has tools for manipulating and analyzing the stored data and for interrelating different types of data. A third and final important element is the visualization and output of data and results of analysis, be it on-screen or in other forms, *e. g.* as maps.

In the Nasca region, the capabilities of GIS could not yet be exploited because of a lack of suitable data. Concerning the geoglyphs which occupy a prominent place in the Nasca landscape, a GIS-based analysis has been needed for some time to help understand the ordering principles that guided their construction:

> "In the future, perhaps GIS analysis will reveal systematic spacing of geoglyphs that we do not perceive from ordinary examination of aerial photographs and maps." (Silverman/Proulx 2002: 179)

The intended photogrammetric analysis of the Palpa geoglyphs in combination with their thorough recording in the field was expected to result in exactly the kind of hybrid data GIS is designed to analyze. Thus, GIS was utilized for data storage, analysis, and visualization as important complement of fieldwork from the beginning of the project.

All in all, in order to document the geoglyphs of Palpa in an efficient and accurate way a new approach combining procedures of modern aerial photogrammetry, archaeological field survey, and GIS technology seemed most promising. Such an approach would allow the establishment of a suitable database indispensable for any further cultural historical investigation into geoglyph function and meaning.

3.2 Geoglyph analysis and interpretation

3.2.1 Previous research

The search for the function and meaning of the Nasca geoglyphs has been the driving force behind their investigation since they were first spotted from a hill east of Nasca by Peruvian archaeologists Julio C. Tello and Toribio Mejía in 1926 (Mejía 2002: 182). Many people, but surprisingly few archaeologists, have since contributed to the topic. The most prominent hypothesis in the popular literature is still that of Paul Kosok and Maria Reiche who considered the geoglyphs "[. . .] the largest astronomy book in the world" (Kosok 1965: 49). To the present day the notion that lines point toward stars and figures depict astral constellations is repeated in newspaper articles and tourist guidebooks. The main reason for the persistence of this explanation is that Maria Reiche, supporter of the astronomical hypothesis, had for many years a quasi monopoly on the interpretation of the geoglyphs and was a media favorite. Although the geoglyphs were first associated with astronomy by American geographer Paul Kosok in 1941, it was Maria Reiche who then promulgated and expanded his explanation.

The origin of the astronomical hypothesis and its basic elements have been described in a series of publications by its main protagonists[20]. They are well known and will not be repeated here. The main aspect of the hypothesis, *i. e.* the alleged orientation of lines or straight sections of geoglyphs towards the rising, setting, or zenith point of the sun and other stars on calendrically important dates (*e. g.* solstice or equinox days), has been thoroughly tested on several occasions by astronomers and other researchers[21]. While the premises and methods of these tests differed, and their results are not identical, all of them show that astronomical orientation can be ruled out as main ordering principle of the Nasca geoglyphs. In spite of these results, the astronomical hypothesis remains today the starting point of current research, such as the project directed by geodetic engineers from Dresden, Reiche's hometown[22]. Therefore, a few critical comments on some often overlooked aspects of Kosok's and Reiche's hypothesis seem appropriate.

The famous story of Kosok being " . . . struck with the thought that these remains could have had some connection with early calendrical and astronomical observations" (Kosok 1965: 52) is often associated with a picture of him standing beside a line that points to the sunset above the flat horizon. This picture, which is not, although sometimes cited as such, reproduced in his 1965 publication, was reportedly taken by his wife Rose (Aveni 2000a: 91) probably someplace on the Nasca *pampa*. If this is true, then it cannot have been taken on June 22, 1941 because on that day Kosok and his wife were standing on the edge of a plateau near Llipata in the vicinity of Palpa, as clearly stated in Kosok's original report (Kosok/Reiche 1947: 202).

[20] Kosok/Reiche 1947, 1949; Kosok 1965; Reiche 1976, 1993.
[21] Hawkins 1974; Aveni 1990b; Ruggles 1990.
[22] Teichert/Richter 2001, 2003; Teichert et al. 2002.

The specific line that pointed to the sunset on that day, a photo of which is shown in the report, runs down the hill and crosses a wide *quebrada* that opens up to the Grande valley. The line is part of a set of lines radiating out in different directions from the point where Kosok was standing, an arrangement today called a line center. To the west, it ended in a large trapezoid (now destroyed) on the left bank of Río Grande. On the right bank of Río Grande a range of rocky hills sharply rises forming a jagged horizon high above the valley. Thus, from where Kosok was standing the line can only roughly indicate a point on the horizon since the horizon is on a considerably higher level than the visible end of the line[23].

What Kosok saw on that decisive day was not a flat horizon where the sun could neatly set over the distant end of a line, but instead a high range of hills, its characteristic peaks and gullies clearly visible against the setting sun. It has been cogently proposed by other researchers that such a setting could have easily served for astronomical observations, since the sunset can be observed over different and easily distinguishable points during the course of the year (Reinhard 1996: 32, fig. 29). For reliable calendric observations in such a setting a fixed viewpoint for comparable observations is the only requirement. Lines or markings on the ground, however, are not needed in such a scenario. Thus, although astronomical observations may have been undertaken, there is little reason to assume that the geoglyphs were related to them – at least not in the way proposed by Kosok.

It may be argued that in a setting lacking a distinctive row of hills, like the Nasca *pampa* as visible in the famous photograph mentioned above, lines served as substitutes for hills that indicated the position of the sun and starts on important dates. If this was true there should be an observable difference in the repertoire of geoglyphs between areas with a flat horizon and others with a hilly horizon. On the basis of available data this question cannot be decided, but there seems to be a high degree of similarity between geoglyphs of different parts of the Nasca region.

According to the astronomical hypothesis lines are not only associated with sunsets, but also with the position of certain stars in the night sky. If this was the case, then ancient observers on the *pampa* would have encountered a practical problem that has rarely been mentioned. The lines on the ground are hardly visible by night, if at all. They could therefore not have fulfilled their alleged function. So far there is no evidence whatsoever that the course of the lines was being illuminated. Such an illumination, on the other hand, would have affected the visibility of the stars. Even in the daytime, the visibility from the ground along a line towards the horizon is often limited, for example due to afternoon haze that makes the horizon appear fuzzy.

Thus, from a practical point of view lines could most likely not have indicated the position of stars and do not even seem especially well suited to indicate sunsets over flat terrain. Furthermore, though lines may be clearly visible over a certain distance, they are in many cases much longer than observable from a ground perspective, a fact that cannot be explained by astronomical observations. Besides, especially on the Nasca *pampa*, a major part of lines are organized around line centers from which they radiate in all directions. Thus, the existing range of line orientations covers practically the full circle. If specific points on the horizon were to be highlighted by the orientation of lines, such an arrangement would not have made any sense[24].

All in all, lines on the ground seem of little value for celestial observations due to practical considerations. This questions the plausibility of the astronomical hypothesis even without addressing the issue of prehispanic astronomical knowledge. Astronomy may well have played an important role in the Nasca region. It seems, however, misleading to relate astronomical activities to geoglyphs. The often repeated notion that the Nasca geoglyphs can only be understood when viewed from above does little to further an understanding of the geoglyphs, nor does the equally well known proposal that looking up into the sky from the *pampa* help

[23] Kosok´s view on that day can be appreciated in pictures published by Morrison (1987: 39) and Moseley (2001: fig. 67). The combination of lines and trapezoids south of Llipata on which Kosok was standing has since been sketch-mapped by Horkheimer (1947: fig. 11; cp. fig. 5) and Rossel (1977: fig. 44) and was interestingly labeled "Línea Sirius" by Reiche (1993: 568–569). It has also been mapped by the Nasca-Palpa Project (supplement 2).

[24] The objections mentioned here address straight lines which Kosok and Reiche originally based their reasoning upon. Apart from straight lines, Reiche and others also checked borders of trapezoids and rectangles, as well as straight portions of bended lines and figures for possibly meaningful orientations. The above mentioned issues apply to them as well.

to understand them. A ground perspective, that is, viewing the geoglyphs from the ground seems the most promising location from which we will be able to learn more about the geoglyphs.

The astronomical hypothesis plays only a marginal role today, at least in scientific research, because it has been tested and largely rebutted. The aforementioned practical issues further bring into question its plausibility. However, fifty years ago, following Kosok's and Reiche's early publications, the notion of advanced astronomical knowledge in prehispanic times manifested by spectacular drawings in the desert made the Nasca geoglyphs world famous. By the 1960s, they attracted *aficionados* from all over the world who tried to explain the geoglyphs from very different viewpoints that were often only loosely, if at all, related to Andean cultural history. Some of these hypotheses are listed in recent reviews (Aveni 1990a; Silverman/Proulx 2002: chapter 7). Rostworowski comments that

> "[a]lgunas hipótesis son extravagantes por la necesidad humana de buscar lo maravilloso, que desligue a la persona de su monótono diario vivir y la haga soñar con extraterrestres y un aeropuerto espacial." (Rostworowski 1993: 190)

Hence, we face a wide range of hypotheses concerning the function of the geoglyphs, running the gamut from landing strips for spacecraft to Olympic runways or pieces of art. Of all these ideas, however, relatively few are based on actual scientific research in, or into, the Nasca region.

The situation has fortunately changed since 1980. In the last two decades several serious investigations of the Nasca geoglyphs have been carried out that have brought about an actual paradigm shift in their interpretation. A review of the results of these recent efforts shows that a general consensus has emerged from them concerning the basic function and significance of the Nasca geoglyphs. For the purpose of the present work, it seems therefore fruitful to review these recent serious contributions in order to identify a starting point for the research presented here. Several overviews of the long history of geoglyph research since 1926 have been written by a number of authors[25]. It is recommended that they be consulted as background information. The following are short summaries of important investigations of the Nasca geoglyphs carried out since 1980 and the implications of that research for this project.

Johan Reinhard

American anthropologist Johan Reinhard studied the Nasca geoglyphs in the early 1980s as part of a broader ethnographic and archaeological investigation into Andean religious concepts and practices (especially mountain worship). His fieldwork in Nasca was limited to the locating of shrines on mountain tops around Nasca (Reinhard 1988, 1996). Basing his arguments on historic sources and ethnographic reports, Reinhard shows that in Andean religious traditions mountain deities played a prominent role and were closely associated with water, weather, and fertility, while their veneration often involved ritual processions along straight lines. Since oral traditions in the Nasca region also speak of mountain deities (namely associated with Cerro Blanco, on the left bank of Río Nasca), he relates the lineal geoglyphs to mountain worship and a cult revolving around water and fertility. It is also a context into which the motifs of the figural geoglyphs fit neatly (Reinhard 1996: 36ff). According to Reinhard,

> "[...] lines played a role in a water ritual by connecting a central place of worship (the mound) with critical places in the irrigation system [...]" (Reinhard 1996: 25)

He assumes that lines were made by kin groups which would explain their great number, and that line centers on elevated points were locations where offerings were placed (Reinhard 1996: 29f).

Reinhard's attempt to interpret the geoglyphs on the basis of Andean religious traditions marks, together with the research undertaken by Aveni and his team (see below), the beginning of a reconsideration of the cultural background of the geoglyphs that had long been neglected. He shows that persistent Andean religious concepts and social organizing principles can potentially explain the Nasca geoglyphs. However, the archaeological evidence that Reinhard offers to support his view is largely restricted to nonspecific references to common finds on and around lines like ceramic vessels or seashells.

Anthony Aveni

American astronomer Anthony Aveni has investigated a wide range of archaeological contexts throughout the Americas with regard to their astronomical significance (for an overview see Aveni 2003). His interest in the Nasca geoglyphs

[25] Morrison 1987; Aveni 1990a, 2000; Lumbreras 2000; Makowski 2001; Silverman/Proulx 2002.

was sparked when he noticed similarities between the geoglyphs and the *ceques*. *Ceques* are imaginary connecting and dividing lines from the Inca period found in highland Cusco and described by Spanish chroniclers (Zuidema 1964; Bauer 2000). Aveni had been investigating them together with Tom Zuidema before he began his work on the Nasca geoglyphs.

In the early 1980s, Aveni led a team of archaeologists, anthropologists and astronomers to study the lineal geoglyphs on the Nasca *pampa* that until then had received less attention than the figural ground drawings[26]. They found that on the Nasca *pampa* more than 700 straight lines are grouped around approximately 70 line centers from where the lines emanate radially, many of them interconnecting several such centers. Thus, a possible order in the lineal geoglyphs on the Nasca *pampa* became discernible (Aveni 1990b). According to Aveni, the radial character of the system of lines that connect centers established on naturally elevated points bears strong structural, and possibly functional resemblance with the Cusco *ceque* system. The radial *ceques* divided and organized the terrain, connected places of religious importance (*huacas*), and were often walked upon in spite of their straightness in rugged terrain. Aveni and his team found ample evidence that the Nasca lineal geoglyphs were equally walked upon, that many of them showed signs of having been used as footpaths, and that they connected

> "[. . .] important points that delineate the flow of water across the pampa: e. g., bends in rivers, dunes overlooking the banks of the rivers and their tributaries, or the last hill by which one descends down onto the pampa as one approaches from the Andes." (Aveni 1990b: 110)

Taking even further the analogy to *ceques* and *huacas* which in highland Cusco were closely associated with certain social groups (*ayllus*), Aveni speculates that Nasca social organization may be reflected in the Nasca line system (Aveni 2000a: 180).

Concerning a possible orientation of certain lines towards astral constellations, Aveni and Ruggles put the astronomical hypothesis to a rigorous statistical test (Aveni 1990b; Ruggles 1990). As a result, they suggest that astronomy might have played a certain role in the construction of some lines, but clearly rule out that it could have served as general organizing principle underlying the system of lines. Summarizing his team's research, Aveni concludes that

> "[. . .] the Nazca lines [. . .] were intended, at least in part, to be walked over in some complex set of rituals that pertained most likely to the bringing of water to the Nazca valley and perhaps to associated mountain worship." (Aveni 1990b: 112)

As already mentioned, the work accomplished by Aveni and his team marks, together with Reinhard's and Silverman's research, the beginning of a new era of scientific investigation into the Nasca lines after the dominance of Maria Reiche's ideas. They have redirected the research agenda toward an Andean cultural framework for interpretation of the geoglyphs. Aveni´s fieldwork showed that a thorough investigation of the lines on the ground, hardly attempted before, can reveal important insights into the nature of the Nasca geoglyphs. However, some shortcomings should not be overlooked.

His research on the *pampa* did not help establish the missing link to the largely unstudied settlements in the valleys – probably one of the reasons why Aveni relies heavily on ethnohistoric and ethnographic parallels to interpret the geoglyphs. Furthermore, like many of his colleagues, he tends to treat the alleged system of lines as a single context, without differentiating chronologically. Finally, he does not present any specific evidence recovered in the field that would clearly support the idea of rituals being performed on the geoglyphs. The same applies to his references to Nasca social organization. Nevertheless, the publication of the results of the investigations of Aveni's team (Aveni ed. 1990) is still the most comprehensive study on the Nasca geoglyphs available.

Persis Clarkson

Canadian archaeologist Persis Clarkson has specialized in geoglyph research in the Americas. Her areas of interest range from the southwestern US to southern Peru and northern Chile (Clarkson 1999). In the early 1980s she took part in Aveni's project, conducting an extensive survey of cultural remains on the Nasca *pampa*. She documented archaeological features like stone circles, cairns, structures and artifacts on and nearby the ground drawings. She tried to establish a cultural and environmental framework for the study of the geoglyphs (Clarkson 1990). Later she continued with her own geoglyph research (Clarkson 1996, 1998).

[26] Aveni ed. 1990; Aveni 1990a, b, 1999, 2000a, b.

Among other things, she investigated the relative and absolute chronology of the geoglyphs (Clarkson 1996; Clarkson/Dorn 1991). Originally she suggested that only the biomorphic figures were from the Nasca period, whereas lineal geoglyphs dated to the Middle Horizon and the Late Intermediate Period (Clarkson 1990: 170). This result did not fit in well with the results of other researchers and was the cause of considerable debate. Based on subsequent fieldwork and chronometric datings Clarkson later changed her point of view[27]. She now agrees that in certain areas lineal geoglyphs also date to the Nasca period.

Concerning the function of the geoglyphs, Clarkson emphasizes that they were walked upon, either in a ritual or profane way. This is suggested by footpaths on the geoglyphs or by the many artifacts found on or nearby them. Clarkson points out that the making of the geoglyphs was an important aspect in itself (Clarkson 1990: 170f). She interprets stone circles and utilitarian ceramic vessels as associated with people working on the construction of the geoglyphs, and suggests that pots of fineware ceramics were intentionally smashed in a ritual context (Clarkson 1990: 140).

Clarkson was the first researcher after a long hiatus to draw attention to archaeological remains closely associated with the geoglyphs that had been virtually forgotten since Mejía and Horkheimer mentioned them in their early reports (Mejía 2002; Horkheimer 1947). Her investigations helped to get a clearer picture of the cultural context of the geoglyphs on a local level, even though not all of the contexts discussed by her seem to be associated with the Nasca geoglyphs. She was also the first researcher to try to date the geoglyphs chronometrically.

Gary Urton

American anthropologist Gary Urton has investigated social and ritual behavior in contemporary communities in both highland and coastal Peru. He has also studied historical sources and recorded oral traditions to trace the observed phenomena back in time. Urton participated in Aveni´s fieldwork on the Nasca *pampa* and contributed important insights from his ethnographic and ethnohistoric research to reconstruct the social background of the people who made and used the Nasca geoglyphs (Urton 1990). He put his focus on patterns of social organization revealed when social groups come together on certain occasions (prescribed by a religious calendar) to maintain public structures. Urton worked back in time from ethnographic reports about contemporary highland communities to ethnohistoric sources that describe the situation in the Nasca region in the 16th century and further on to archaeological evidence from Inca times. He argues that pre-conquest Nasca society was structured in a three level hierarchy.

According to Urton, local level *ayllus*, groups of people holding common land rights on strips of terrain, were grouped on the regional level into *suyus* or *parcialidades* while several of these middle level units were in turn grouped into moieties that were basic elements of the dual organization of pre-conquest Andean societies well documented in historic sources (Urton 1990: fig. IV.12). Concepts of social organization, like *ayllus*, were at the same time closely associated with concepts of spatial organization, like *chhiutas* or strips of land. According to Urton, the persistence of these concepts from prehispanic well into modern times (although not unaltered) favors their projection back into Nasca times. He argues that the maintenance of the Nasca lines can be understood in terms of communal labor organized along *ayllu* lines, *e. g.* to maintain an alleged trans *pampa* road. This work could also comprise ritual activities, like the cleaning of sacred spaces as prelude to ritual processions or gatherings.

Although Urton's work has little to offer in terms of archaeological evidence from the geoglyphs, it presents a coherent model of a possible social organization for the period when the geoglyphs were constructed. Furthermore, it favors, much like the contributions of other researchers described in this section, a ritual use of the Nasca geoglyphs at least in part.

Helaine Silverman

American archaeologist Helaine Silverman conducted extensive fieldwork in the Nasca region in the 1980s and has since published an important series of articles and books on a wide range of topics about the prehistory of that region. Her main projects were excavations in Cahuachi (Silverman 1990a, 1993a) and a regional settlement survey of the Ingenio valley (Silverman 1990b, 1993b, 2002b). In spite of the considerable number of excavation and survey projects in recent years, Silverman's publications are still the only final reports available on this kind of research.

[27] Clarkson 1996: 437, 1999: 169; Clarkson/Dorn 1991: cuadro 1.

Silverman's work does not focus especially on the geoglyphs. She does not treat the geoglyphs as an isolated phenomenon like many of her predecessors, but rather as an integrated part of a culture to be studied and understood only within their cultural historical context. In the vicinity of Cahuachi and also in the Ingenio valley, Silverman noticed that geoglyphs are often found in close proximity to settlements, point towards them or even interconnect them. Thus, a cultural context on the regional level could be reconstructed which the geoglyphs on the *pampa* seemed to be devoid of at first sight. Drawing upon her interpretation of Cahuachi as the spiritual, ritual, and social (albeit not political) center of Early Nasca times, Silverman understands the geoglyphs as part of a ritual complex closely related to that site. Thus, she interprets lines through the *pampa* as pathways used by pilgrims on their way to Cahuachi, as culturally domesticated space in the desert, and as locus of gatherings and ritual activities of cognatic descent groups (Silverman 1994b, 2000).

Like Urton, Silverman believes that Nasca sociopolitical organization can be understood in terms of Andean dualism. In this model, the Nasca drainage would have been divided into two moieties north and south of the Nasca *pampa* with each valley in turn split into an upper and lower moiety. The *pampa*, and with it the geoglyphs, would have served as a place or stage where people from the two moieties met, interacted, and negotiated their status. While historic documents from the early colonial period seem to support the idea of intra-valley moieties prior to the conquest (Urton 1990: appendix III), Silverman finds further support for her idea in the proposed functional division of Cahuachi, the empty ceremonial center in the Nasca valley, and Ventilla/Site 165 which is the alleged urban and administrative center in the Ingenio valley. Silverman believes that both sites were connected by a trans-*pampa* geoglyph which would again strengthen the idea of the *pampa* as connector and common ground for both moieties.

However, there are many unknowns in Silverman's equation. The geoglyph she cites in her research was built over by the *Camino de Leguía*, predecessor of the Panamerican Highway, in the 1920s before the first aerial images of the *pampa* were taken, so it is difficult to assess today if such a geoglyph ever existed. Furthermore, Ventilla/Site 165 has never been investigated in detail, and there are serious doubts concerning the purely ceremonial role of Cahuachi as proposed by Silverman (Schreiber 1998: 265). Hence, apart from historical sources mentioned by Urton and the claim that the concept of Andean dualism can be traced to Nasca times, there is still no clear archaeological evidence to back such a model.

More than other researchers Silverman emphasizes that the hypotheses proposed by Aveni, Urton, Reinhard, and herself complement each other. In her view the construction of geoglyphs was based on a ritual complex involving ritual movements along straight lines, prediction of water flow and agricultural fertility, observation of the skies and heavenly bodies, and mountain worship. She furthermore understands the geoglyphs as a mnemonic device or text seeing

> "[...] the proliferation of lines on the Pampa as the cumulative result of repetitive ritual activity, perhaps calendrically organized [...] Through this ritual activity on the Pampa the lines were made and in so doing the lines recorded ecological, climatological, hydrological, social, and political information necessary for social life and its prediction and scheduling." (in Silverman/Proulx 2002: 179)

The function of specific geoglyphs in regard to the different aspects of Silverman´s hypothesis remains vague, however. The strength of Silverman's reasoning lies in a logical model that explains the geoglyphs in a larger cultural context, but data from the archaeological record is underrepresented in her model.

David Browne

British archaeologist David Browne was the first researcher to concentrate his investigations exclusively on the then poorly known Palpa area. His survey, conducted in the late 1980s, covered the alluvial plain around Palpa, the Río Grande downriver to its junction with Río Ingenio, as well as short stretches upriver of Río Grande, Río Palpa and Río Viscas[28]. Although the geoglyphs were not the focus of his prospection (Browne 1992: 77), he describes several which he found in close proximity to sites from the Early Intermediate Period. The term *campo barrido* or cleared field used by him (Browne/Baraybar 1988: 301, 309) seems to refer in most cases to some kind of cleared *plaza* forming a part of a settlement, but in other cases it is clear that

[28] Browne 1992; Browne/Baraybar 1988; Silverman/Browne 1991; Browne et al. 1993.

Browne describes trapezoidal geoglyphs. He proposes a ritual function for the *campos*, possibly related with funeral rites, but does not explain what this assumption is based on other than some intentionally broken pots. Concerning geoglyph research in general, Browne states

> "[...] that the clues to the answers to many problems concerning the so-called Nasca lines lie in the small valleys tributary to the main drainage and that the emphasis in study should shift from the pampa to them." (Browne/Baraybar 1988: 318)

While this conclusion is important, published data on the geoglyphs in his survey area is limited.

María Rostworowski

Peruvian historian María Rostworowski has searched a vast number of historical sources for indications of pre-conquest history and religion in the Andes. Her publications constitute an important source of information on these topics. According to Rostworowski, old legends found in colonial sources indicate that a deity called Kón was venerated before the god Pachacamac rose to prominence (Rostworowski 1993). Kón is said to have changed the once fertile coastal strip into desert and to have sent rivers as substitute for rain. Thus, this deity is closely associated with the flow of water in the rivers upon which the coastal economy is based.

Kón is described as a boneless, flying being, whose origin can be traced to the south coast. Based on this evidence, Rostworowski hypothesizes that Kón may have been the principal deity in the Paracas and Nasca pantheon and that this deity probably appeared only at certain seasons of the year when the water in the rivers began to flow (Rostworowski 1993: 196, 199). She also assumes that the geoglyphs were made as places where believers awaited Kón's appearance or as signs for the god to come. Water and fertility would have been important aspects of this religious concept, not only in Paracas and Nasca but throughout the whole Peruvian coast. Rostworowski also identifies flying beings depicted on ceramics and textiles that are generally characterized as Anthropomorphic Mythical Being as Kón.

Apart from Silverman´s and Proulx´s objection that the Anthropomorphic Mythical Being is not related to flying (Silverman/Proulx 2002: 185), Rostworowski´s hypothesis has the disadvantage that there will probably never be a way to test it with archaeological means. However, it fits well into the aforementioned attempts to explain the Nasca geoglyphs in terms of Andean religious concepts and beliefs.

Aurelio Rodríguez

Peruvian archaeologist Aurelio Rodríguez has studied geoglyph sites on the coast of Peru, especially in the vicinity of Lima. In order to establish an interpretative framework for analysis, he searched historical sources from the early and middle colonial period for accounts of ritual practices during the precolonial era (Rodríguez 1999). Although the Nasca geoglyphs were not the principal focus of his study, he applied much of his results to them since they are the best known complex of geoglyphs. Rodríguez argues that the geoglyphs served as locations for what he calls *desplazamiento ritual* or ritual movement (Rodríguez 1999: 10, 13) which he subdivides further into processions/ pilgrimage, ritual races, and dances. For each of his three subcategories he presents detailed accounts from colonial sources describing how these rituals were performed on marked spaces. According to his hypothesis, long straight lines served for processions and pilgrimage while ritual races were carried out on trapezoids and their adjoining lines. Ritual dances in turn would have been performed on figural geoglyphs with chains of dancers moving along the lines that form the figure.

Rodríguez' compilation of historical accounts results in a coherent picture of Andean ritual practices and seems to fit neatly to the Nasca geoglyphs which were presumably marked spaces where such rituals were preformed. Rodríguez is more specific than other researchers as to the actual activities on certain types of geoglyphs. Nevertheless, he too faces the basic problem of an 800 year time gap between the period of use of the Nasca geoglyphs and the historical accounts he cites, and he offers no specific archaeological evidence to sustain his ideas.

David Johnson

Whereas Aveni and other researchers propose a possible relationship between geoglyphs and rivers, American independent scholar David Johnson recently proposed a new hypothesis that links the geoglyphs to subterranean water sources (Johnson 1999; Johnson et al. 2002). According to Johnson, geoglyphs mark the course of aquifers that run through geological faults and intersect the valleys where water from them is captured in wells and filtration galleries.

Johnson postulates a recurrent pattern of faults, aquifers, settlements, filtration galleries, and geoglyphs occurring together (Johnson et al. 2002: 309). He even proposes some kind of "code" for the geoglyphs: trapezoids mark the course of aquifers, zigzags show places without subterranean water, etc. (Johnson 1999: 160).

Fieldwork recently conducted by American hydrogeologist Stephen Mabee to test Johnson's hypothesis shows that there is indeed strong evidence for water sources in the valleys that are independent of the rivers and are apparently supplied by aquifers carrying water from the highlands through subterranean courses towards the coast[29]. It is important to note that at least some of the ancient filtration galleries were constructed so as to tap the water from these aquifers, thereby providing an additional water supply that was certainly of great importance for the inhabitants of the valleys. It also comes as no surprise that ancient settlements are clustered around areas where reliable water sources were available.

However, the proposed relation of subterranean water to geoglyphs is not evident in the data provided by Johnson. Although he presents photos and sketches showing that some trapezoids align with faults likely to carry water, it has to be kept in mind that the desert zone close to the valley is the area where most geoglyphs are found, so any relation may be no more than coincidental. To systematically investigate a possible relation between geoglyphs and water, a detailed documentation of all existing geoglyphs is needed which Johnson fails to present. Furthermore, some aspects of his reasoning seem questionable, *e. g.* his consideration of stone circles which are most probably of modern origin. In summary, the core of Johnson's hypothesis thus far lacks support from field data. However, the work by his colleague Stephen Mabee is an important contribution to Nasca research since it helps understanding ancient water management.

3.2.2 Review of recent investigations and research approach

The above review of recent investigations demonstrates that Nasca geoglyph research has advanced considerably since 1980. Andean cultural concepts, religious practices, and social organization are now used as the basis for new hypotheses to explain the origin and the nature of the geoglyphs. These new approaches are quite distinct from that of Maria Reiche who dominated the debate on the Nasca geoglyphs, as well as the geoglyphs themselves, for several decades. When Kosok and Reiche proposed their astronomical hypothesis, they largely abandoned what was then known to researchers about Andean cultural history. Although their approach was not in itself unreasonable, their tendency to neglect the cultural context of the Nasca geoglyphs prepared the ground for many unscientific and even fantastic ideas that were proposed in the '60s and '70s to explain the Nasca geoglyphs.

The Andean model

This tendency to explain the geoglyphs using unscientific hypotheses has been clearly reversed since 1980, when Nasca geoglyph research began to look again at the Andean cultural context. The aforementioned recent approaches are interestingly quite similar to the earliest attempts to interpret the geoglyphs. For example, Mejía, one of the rediscoverers of the geoglyphs explained them as sacred pathways and was the first to compare them to the Cusco *ceques* (Mejía 1942, 2002). Horkheimer argued that the geoglyphs were manifestations of an ancestor cult that involved dances along the lines performed by kin groups (Horkheimer 1947). Clearly, both these early researchers and their present-day colleagues have been striving for embedding the Nasca geoglyphs into a broader context and for explaining them on the basis of current knowledge on Andean cultural, religious, and social traditions. It is also clear, as Aveni, Silverman and Proulx pointed out, that most of the hypotheses presented previously can be combined into a single model[30] (Aveni 2000a: 209; Silverman/Proulx 2002: 192). Such a model will be termed "Andean model" for the purpose of the present study, and it is summarized as follows:

> The Nasca geoglyphs were made by a population organized in social groups whose members shared common ancestors and/or land rights. These groups met in the desert, marking and creating space according to common concepts and beliefs deeply

[29] Johnson 1999: 159; Johnson et al. 2002; cp. summary in Silverman/Proulx 2002: 185–189.

[30] The term "model" is used in two different ways in the present study. Archaelogically, a "model" is a set of hypotheses aimed at explaining archaeological data in a wider context. In geomatics, on the other hand, the term refers to the geometric representation of a real-world object.

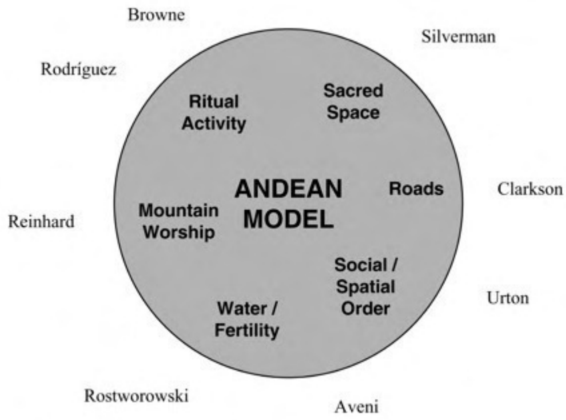

Fig. 5. The Andean model.

embedded in Andean traditions. This social interaction was important for the position of each group within a broader societal context. A cult revolving around mountain deities, water flow, and fertility, probably organized by a ritual calendar, was the background of geoglyph related activity. The geoglyphs were organized in a spatial system that reflected social order, since they were associated with social groups and determined their status. They furthermore connected sacred places and were in some way or another related to the course of water. The geoglyphs served for processions performed by the groups that made and maintained them. These movements might have been related to pilgrimage, sacred sites, or other traffic across the desert. Fineware ceramic vessels, supposedly filled with food and drinks, were ritually smashed and placed on line centers and along geoglyphs. Trapezoids were places where larger groups gathered or races were held, while biomorphic figures, whose motifs evoked the concept of fertility, were walked upon in dances. The geoglyphs marked social, cultural, and sacred space out in the desert. They symbolically expressed cultural concepts that could be understood by members of Nasca society. Superposition of geoglyphs reflected evolution of the cultural and social reality. All in all, the geoglyphs were deeply embedded in the daily life of Nasca society, and the basic concepts that guided their realization were in concordance with Andean cultural, religious, and social traditions.

For clarification, the main aspects of the Andean model as well as its contributors are illustrated in figure 5.

The Andean model, though neither designated nor formulated as such by any of the above mentioned researchers, represents the state of the art in Nasca geoglyph research. Its basic assumption is that the Nasca culture was part of a long-term cultural tradition shared throughout the Andes that evolved slowly in time and proved persistent over the centuries. It is further assumed that this Andean tradition which involves common concepts of beliefs and behaviors persisted in a somewhat altered form through the period of the Spanish conquest, and is found today in Andean communities. Following this reasoning, ethnographic and ethnohistoric studies not only allow identification of elements of this tradition, but also enable the establishment of a causal link between observed behavior and material culture. For example, Urton explains spatial division of the churchyard of Pacariqtambo, a contemporary village in the highlands, with social division of the community (Urton 1990). Aveni, basing his arguments on accounts of early Spanish chroniclers, explains the arrangement of *huacas* and *ceques* in prehispanic Cusco in terms of Inca social organization and religious practices (Aveni 1990b).

In the case of the Nasca geoglyphs, only the remains of material culture can be documented archaeologically while the cultural concepts behind them are nowhere described. However, the assumption mentioned above that a long-lasting Andean tradition is the common framework for the Nasca geoglyphs, the Cusco *ceques*, and the Pacariqtambo churchyard strips, allows the establishment of an analogy on the basis of which conclusions can be drawn about the unknown concepts behind the geoglyphs (Bernbeck 1997: chap. 5). Accordingly, Urton and Aveni, as well as Rodríguez and Silverman, use current social organization and religious practices found in ethnographic and ethnohistoric research in order to interpret the function and meaning of the Nasca geoglyphs. The result is a coherent set of hypotheses here called the Andean model that can be used to explain the Nasca geoglyphs.

Critical comments on the Andean model

How can the validity of the Andean model be assessed? In archaeological research an explanatory model cannot be proven, and while it may be capable of explaining certain archaeological contexts, other models might have the same capability as well. Thus, the model has to be assessed in terms of plausibility. This can be done in two ways. On the one hand, the analogies used to establish the model can be questioned, considering aspects like the time interval between compared phenomena and their degree of similarity. Such an approach may clarify the theoretical foundations of the model. On the other hand, archaeological fieldwork offers the opportunity to verify or contradict the material foundations of the model. As has been shown, the Nasca geoglyphs are poorly researched archaeologically. New research may either corroborate the plausibility of the model or necessitate its modification or replacement.

Concerning the plausibility of the analogies established between the Nasca geoglyphs and later contexts such as the Cusco *ceques*, it has to be kept in mind that starting from the general consensus that the geoglyphs were mainly made and used at the time of the Nasca culture, there is a time gap of almost a millennium between the last constructed geoglyphs and descriptions provided by colonial written sources. In this considerable time span the Nasca region faced several historic disruptions. Therefore, Proulx cautions that

> "[...] Nasca culture had disappeared almost eight hundred years prior to the emergence of the Inca Empire and was separated from it by the Tiwanaku/Wari religious tradition which was quite different from earlier Nasca religion, not to mention the different political context." (in Silverman/Proulx 2002: 195)

These disruptions are primarily indicated in the archaeological record by changing ceramic traditions, notably different settlement patterns, and the end of the geoglyph tradition. The Spanish conquest was yet another major historic disruption. Thus, there is no smooth continuity between the Nasca geoglyphs and the time of the earliest chronicles.

However, in spite of these disruptions there may still be a persistent tradition. The fact that certain religious practices and principles of social organization in the 20th century are similar to those described in the 16th century indicates that in spite of major historic breaks and disruptions there is a stable cultural foundation upon which Andean societies are based. Thus, to use colonial documents to try and understand the Nasca period is reasonable, although it should be kept in mind that even such a stable tradition is slowly changing. The change may be minimal over a short time span, but if at least 800 years and several major historic changes are to be bridged then it is to assume that a change in certain aspects occurred. Thus, the task remains to find out what aspects changed, and to determine the degree of change.

The usefulness of using ethnohistoric and ethnographic accounts to establish the Andean model can be assessed by considering the degree of similarity between compared phenomena. In the case of the Nasca geoglyphs it has become clear in section 3.1 that any comparison is rendered difficult due to a lack of archaeological data. In the literature, references to the actual archaeological record are sparse. Apart from some notable exceptions there is no detailed description of specific geoglyphs. Even recent projects largely have failed to produce or at least to publish a comprehensive database that would allow other researchers to get a precise idea of the properties or even the location of specific geoglyphs. Instead, common characteristics supposedly shared by the majority of the Nasca geoglyphs are often summarily described, *e. g.* the straightness and radiality of lines, the subtractive construction technique of most geoglyphs, sherds of broken pots scattered around geoglyphs, etc. These general traits are repeatedly mentioned and thus perpetuated in the literature. The fact that a serious attempt to document the Nasca geoglyphs has yet to be undertaken renders any generalization doubtful since many different geoglyphs contexts have not thus far been considered. Thus, the use of ethnographic or ethnohistoric analogy may have a weak point concerning traits that are compared with the archaeological record. Archaeological fieldwork is required to verify ethnographic and ethnohistoric analogy, and this is the focus of this study. The more geoglyphs are documented the better we will know if certain characteristics of the geoglyphs are typical or representative. These can then be compared with ethnographic or ethnohistoric contexts.

If archaeological fieldwork is aimed at assessing the Andean model, then three basic issues should be pointed out:

- The model primarily attempts to explain the geoglyphs on the Nasca *pampa* without consideration of the wide variety of existing geoglyphs
- The model does not take into account the vast time span during which the geoglyphs were made
- Several aspects of the model are not testable by archaeological methods.

Concerning the first point, the Nasca *pampa* is not only the principal destination of tourist flights, but has also attracted most scientists who worked in the Nasca region. While early researchers were quite aware that geoglyphs are a phenomenon not restricted to the Nasca *pampa*, later research focused almost exclusively on that vast plateau and, more specifically, on its northern edge. The only exceptions are Silverman and Browne who called attention to geoglyphs in other areas very different from the *pampa*. Many geoglyphs along the tributaries of Río Grande can be found in close proximity to settlements. They are part of less complex sites or even isolated from one another, and occur in different topographical settings. The Andean model, however, is largely tailored to explain the maze of geoglyphs that cover the vast, uninhabited flat *pampa*. Different manifestations of the geoglyph phenomenon in other regions of the Nasca drainage may thus not be explained by using the Andean model.

Concerning the chronology of the geoglyphs, they are generally thought of having been made over approximately 1,000 years. Over such a long time span, cultural change can be expected to affect the construction, use, perception, and physical manifestation of geoglyphs. Thus, it is already clear that the Andean model has to be improved by adding time depth. Geoglyph chronology is still fraught with uncertainties. It relies mainly on dating by using associated ceramics whose chronology has yet to be verified stratigraphically. Such indirect dating presents a constant methodological problem because in most cases the actual temporal relation between a geoglyph and the sherds found on it cannot be established unambiguously. The potential of relative chronology (based on the stratigraphic relation of one geoglyph to each other or to other cultural remains) has not been fully exploited because of a lack of a detailed record of the geoglyphs. The same applies to chronometric dating of the geoglyphs. Thus, it is not clear if different shapes and sizes of geoglyphs or different contexts and combinations can be explained chronologically rather then functionally or regionally. Furthermore, the maze of geoglyphs that we see today makes it difficult to keep in mind that most probably only a small number of them were used together at any given time. Therefore it is clear that any interpretation of the geoglyphs can only make sense if it takes into account chronological variation.

Finally, it has to be kept in mind that certain aspects of the Andean model cannot be tested by archaeological methods. For example, Rostworowski's idea that the god Kón was venerated on the Nasca *pampa* cannot be verified archaeologically. In the case of other aspects a basic question from archaeological fieldwork remains unanswered, namely: How will archaeological remains appear if predicted by the model? How can kin groups, ritual dances or mountain worship be detected by archaeological methods? What material traces of pilgrimage or a ritual calendar may be preserved? The literature reviewed above provides few clues to answer these questions.

The archaeological record is composed of material remains, and in this case the remains are geoglyphs as well as other artifacts and structures associated with them. Their study may reveal geoglyph related activity and people involved in it. Intangible concepts such as traditions or systems that motivated or induced geoglyph related activity can be assessed only indirectly. Thus, only certain aspects of the Andean model, namely those related to material culture and activities that lead to the formation of the archaeological record, can be directly tested. The main explanatory aspects of the model, *i. e.* those dealing with Andean concepts and cultural traditions, are almost impossible to test for archaeologically. However, once archaeological data becomes available, they can be assessed in a better substantiated way.

Based on these premises it was decided to analyze the Palpa geoglyph data in a series of steps. The development of the geoglyph typology of the Palpa sample helped to generate a systematic overview of the formal variation of the geoglyph repertoire. Using stratigraphic and contextual evidence a general chronological framework for the geoglyphs was then established. This step furthermore allowed the typological variety within the Palpa geoglyph sample to be examined to determine if it can be explained chronologically. Thus, variety and chronology of the Palpa geoglyphs were addressed first.

In the next step, activity related to the Palpa geoglyphs found in the archaeological record was identified. This allowed acquisition of a clear picture of what actually happened on geoglyph sites, which is a question of central concern to the Andean model. Other aspects of the model that postulate a link between the geoglyphs and their environment were then addressed by a GIS-based spatial analysis of the

Palpa geoglyphs that revealed ordering principles for geoglyph placement, shape, etc.

3.3 Summary: Geoglyph research in the Nasca region

The above review shows that previous research on the Nasca geoglyphs has resulted in a comprehensive hypothetical model to explain the geoglyphs. This model should be tested with archaeological data, and as the review indicates, any new attempt to study the geoglyphs only makes sense if it includes the acquisition of a fresh body of field data. The Nasca-Palpa Project was intended to address some of these research problems by a comprehensive documentation of the Palpa geoglyphs and by comparing archaeologically testable aspects of the Andean model with the data obtained.