The Lake Bosumtwi impact structure in Ghana: A brief environmental assessment and discussion of ecotourism potential

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Abstract—Lake Bosumtwi is a natural inland freshwater lake that originated from a meteorite impact. The lake is becoming a popular tourist attraction in Ghana and has the potential to be developed as an ecotourism site in the future. However, there have been some unregulated human activities and unplanned infrastructure development, and there are increased levels of pollutants in the lake water. In order to make ecotourism at Lake Bosumtwi successful in the long term, the Lake Bosumtwi Development Committee has been formed to ensure that local people are empowered to mobilize their own capacities. It has been realized that an important criterion required to develop ecotourism in a socially responsible, economically efficient, and environmentally viable way is to foster a constructive dialogue between the local people and tourists about the needs of the indigenous people.

INTRODUCTION

The Bosumtwi impact structure is exposed in 2.1 Gyr Precambrian metasedimentary and metavolcanic rocks in the forest zone of southern Ghana (06°30′N, 01°25′W). It is a well-preserved 1.07 Myr complex impact crater 10.5 km in diameter with a pronounced rim. The crater is almost completely filled by Lake Bosumtwi, which is ~8 km in diameter and up to 78 m deep at its center. Bosumtwi is associated with one of only four known tektite strewn fields (the Ivory Coast tektites) (Koeberl et al. 1997). Details on the geology of Bosumtwi and the controversies surrounding the acceptance of the impact origin, and on a recent drilling project that was supported by the International Continental Scientific Drilling Program (ICDP), the Ghana Geological Survey Department, Kwame Nkrumah University of Science and Technology (KNUST), and various funding organizations in Austria, Canada, and the USA, are given by, e.g., Koeberl and Reimold (2005), and references therein (also Koeberl et al. 2007).

The local people mostly farm and fish, but recently tourism has evolved as an alternative source of income, providing them with new employment opportunities, new infrastructure development, and government revenue. However, unorganized and unplanned tourism development, which is characterized by overcrowding, misuse of natural resources, insensitive tourist behavior, mismanagement of waste disposal, and uncontrolled infrastructure development, can have negative impacts not only on the natural environment but also on the social and cultural values of the local communities (see, e.g., Prakash et al. 2005).

Lake Bosumtwi, being the main attraction (see Prakash et al. 2005) for ecotourism in the region, needs to be protected and conserved because the increase in development around the lake of the past years translates into an increase of pollution within the lake basin, which could mean a premature end to ecotourism development in the Lake Bosumtwi basin. A major concern is that the lake is in a closed hydrological basin (Fig. 1) (Turner et al. 1996a, 1996b), so all pollutants remain in the lake, and concentrations will increase in the future. There is, therefore, the need for comprehensive research on the state of the water quality of the lake. Here, we briefly assess the problems related to the environment and the potential of ecotourism development in the Lake Bosumtwi basin by looking at the state of the lake and its natural environment, and discuss the current status of tourism development.

HYDROLOGY AND BIOGEOCHEMISTRY OF LAKE BOSUMTWI

The lake currently has no outlet, although it has apparently overflowed in the recent geologic past (e.g., Turner et al. 1996a). The most important controls on the water balance of the lake are rainfall directly onto, and water evaporating directly from, the surface of the lake (Turner et al.
Of lesser importance is the runoff contributed by the lake’s surrounding watershed. It is reasonable to assume, when considering the hydrogeological conditions, that little or no groundwater enters or leaves the basin. According to Turner et al. (1996a, 1996b), the lake level is very sensitive to small changes in rainfall and other climatic parameters, such as annual mean temperature and evaporation.

Although the lake is homogeneous with respect to major ion composition, it is stratified into an upper oxygenated layer and a lower anoxic layer, and there is an abrupt change in the concentration profiles of pH, $\text{NH}_4^+$, $\text{PO}_4^{3-}$, $\text{NO}_3^-$, and Mn at a depth of 16 m (Turner et al. 1996b; see also data of a new study by Hecky and co-workers as cited in Koeberl et al. 2007). Previous studies of the chemistry of waters within the basin, according to Turner et al. (1996b, and references therein), included chemical analyses of lake-water samples taken in 1934 (McGregor 1937) which indicated a sodium bicarbonate water of low salinity and high pH; and chemical data from some of the streams running into the basin (Whyte 1975). It should be noted that owing to decomposition of organic matter in lake sediments, the lake water has “turned over” in the past, leading to anoxic conditions throughout the water column and, thus, to mass death of the fish population (e.g., Rattray 1923). Studies of Lake Bosumtwi sediments have included chemical analyses of two lake-mud samples (McGregor 1937) that gave the following results calculated on a water-free basis: 0.76 and 0.35 wt% total sulfur and 8.36 and 3.82 wt% organic carbon, respectively. These values indicate a high input of detrital organic matter. This is also supported by variations in carbon and nitrogen isotopic compositions of bulk organic matter in sediments (Talbot and Johannessen 1992) that reflect climatically induced changes to the lake and the catchment flora. Organic pollution may present a problem in lakes such as Bosumtwi (Ansa-Asare et al. 1999).

**ENVIRONMENTAL ASSESSMENT**

The main environmental issue at Bosumtwi is pollutants being added to the lake. Potential sources of pollutants are: 1) agricultural activities, 2) domestic activities, and 3) atmospheric deposition. The Bosomtwe-Atwima-Kwanwoma District (http://bak.ghanadistricts.gov.gh) is one of the 21 districts in the Ashanti Region, and in 2002 had a total population of about 146,000 people (http://www.statoids.com/ygh.html), of which about 30,000 live within the Bosumtwi watershed (Prakash et al. 2005; http://www.ghanadistricts.com/districts). As elsewhere, a link between population size and pollution is likely.

**Agricultural Activities**

The Lake Bosumtwi basin is home to a rural community consisting predominantly of farmers. Some of the men in the community are also fishermen. The people cultivate different kinds of crops including mainly plantain, cassava, cocoyam, and various other vegetables, with cocoa being the major cash crop.
Use of Agrochemicals (Pesticides and Chemical Fertilizers)

Chemical fertilizers are not intensively used in the lake basin because farming is carried out in a traditional way and most farmers cannot afford fertilizers. However, in recent years, the government, through the Ministry of Food and Agriculture, has started supplying chemical fertilizers (e.g., Cocofood [NPK]) to increase the cocoa yield. Also, the use of pesticides (e.g., DDT) and some growth-enhancing chemicals (e.g., Gamalin 20 and Cocostar) to spray crops, especially cocoa, has been increased. Pesticides are necessary because of damage to the cocoa crop by mirids (a type of sucking insect), which, together with mealybugs and the black pod disease, are the three pests that most affect cocoa in Ghana and other West African countries. The use of agrochemicals is therefore expected to increase as more farmers are turning to cocoa farming (e.g., Gerken et al. 2001). That the use of pesticides presents a problem not only for the farmers who are exposed to them (Clarke et al. 1997), but also for the consumers and the water supply, has been demonstrated by, e.g., Ntow (2001, 2005), Ntow et al. (2006), Otchere (2005), and Amaoah et al. (2006). These authors showed that in Ghana, pesticide and organochlorine residues (as well as fecal coliform contamination) are found on vegetables, in soil, and in the water supply, constituting a serious health risk. In particular, Ntow (2005) and Otchere (2005) confirmed the presence of organochlorines (pesticides and polychlorinated biphenyls [PCBs]) in water bodies in Ghana that are similar to Lake Bosumtwi—only with smaller relative populations. This makes the lack of similar studies at Bosumtwi even more worrying.

Livestock and the Use of Organic Fertilizers

There is quite a large population of livestock in the communities around the lake. Because of their large numbers, their impact on the lake is substantial. Animals such as sheep, goats, and pigs reared in the community defecate along the banks of the lake while grazing and drinking from the lake. Because of this, it is likely that a large portion of the droppings (containing nitrogen and phosphorus) end up close to the shore and will be washed into the lake by the rain. Some people have started using some of the droppings as fertilizers.

Land Use (Farming) and Fishing

More people of the communities around Bosumtwi rely on agriculture than on fishing (Prakash et al. 2005). Agricultural production in the lake basin is done with simple farm tools such as the cutlass and hoes. There is, therefore, an increase in the utilization of unsustainable natural resources in terms of land cultivation, overgrazing, and forest exploitation. One consequence of this is increased soil erosion, which results in more nutrient runoff and leaching. Besides that, clearing and slash-and-burn practices have a direct influence on the atmospheric deposition of nutrients. When it rains, surface runoff water washes away the soil nutrients and all the streams in the farmlands flow directly into the lake, causing enrichment of the lake water (eutrophication). The pollutants also end up in the lake through leaching into the groundwater. The groundwater is in connection with the lake water and seeps through the soil into the lake. The communities around the lake depend heavily on fishing, as indicated by the abundance of fishing nets that are set all over the lake. However, there are two problems associated with the fishing activities that have so far not been addressed. First, the increasing population around the lake is leading to more and more fish being taken from the lake, potentially resulting in overfishing. Already there are indications that mainly smallish fish can still be garnered. Second, the increasing use of pesticides in farming, as well as the input of anthropogenic pollutants as mentioned above, during the past decades most likely has already resulted in the fish being contaminated with various chemicals—but so far no studies have been made to assess the contamination status of the fish in Lake Bosumtwi. Due to the population increase around Lake Bosumtwi, it has become clear that fishing and farming activities cannot be sustained indefinitely.

Domestic Activities

Domestic pollution loads are directly related to the population size. About 30,000 people currently live within the lake basin or its immediate environs.

Use of Detergents and Soaps in the Lake

Clothes are washed with detergents in the lake water and also at the bank of the lake shore where the used water is eventually thrown into the lake. Cars are also washed with detergents along the bank of the lake shore. Some of the people in the community bath with soaps in the lake water and fishermen wash their nets with soap in the lake.

Burning of Organic and Inorganic Waste along the Lake Shore

Regularly, the lake banks are weeded and the weeds are collected and burnt; also, plastic found at the banks is collected and burnt. This is supposed to be part of the community-sponsored environmental program to clean the lake shore. But burning of PVC (polyvinyl-chloride), the world’s second-most common plastic, releases highly poisonous dioxins into the atmosphere. The ash is left on the bank and eventually carried into the lake by wind and rainwater.

Increasing Human Activity Close to the Lake

Human activity close to the lake is increasing with several accommodation facilities, including hotels, springing up next to the lake. The inorganic waste and wastewater management from such facilities has not yet received much attention from the local authorities. Because there is no Environmental Impact Assessment (EIA) plan for how to deal with the waste, all the waste originating from these accommodation facilities will end up in the lake.
Disposal of Garbage

There is indiscriminate littering at the bank of the lake with plastic materials from food vendors and sellers of other products. Some of these eventually find their way into the lake. Generally speaking, there is uncontrolled disposal of solid waste, as there is no serious waste management system in place. In some cases, refuse washes into the lake during rainy periods (Prakash et al. 2005).

Atmospheric Deposition

Land clearing and slash-and-burn practices in the agricultural sector substantially add to emissions into the atmosphere. Aside from this, the nearby urban area of Kumasi may add to atmospheric deposition through extensive burning of biomass, car exhaust emissions, and other forms of air pollution. Because the main source of water into the lake is rainfall, pollutants in the atmosphere return to the lake. The main source of energy (for cooking) of the people of the communities living around the lake is fuel wood.

It should be noted that until the 2004 ICDP drilling project at Lake Bosumtwi, no detailed pollution study (lake level, development with time, or in/out pathways) had ever been done. Such a study is a precondition for assigning ecotourism value to Bosumtwi. A hydrological/limnological study by R. Hecky and collaborators of the water column before, during, and after the ICDP drilling project was done and indicated no influence of the drilling operations on water quality; data from this study (still in progress; see also Koeberl et al. 2007) will provide important baseline information for a detailed pollution study.

Lake Bosumtwi is situated in the famous Ashanti gold belt of Ghana (Kesse 1985) where many private companies are carrying out exploration. However, a 10 km wide buffer zone around the lake, within which mineral exploration and mining activity are prohibited, has been established by the Geological Survey Department and the Ministry of Mines since the beginning of 2006 to prevent further pollution by any future mining operations.

ECOTOURISM POTENTIAL

Lake Bosumtwi is becoming a popular tourist attraction in Ghana and has the potential to be developed as an ecotourism site. Following Prakash et al. (2005), the attractions related to tourism at the lake include:

• the lake itself for recreation and aesthetic values
• suevite outside the crater rim and its importance for impact-cratering studies
• rich geological and biodiversity information
• rural landscapes, lifestyles, and cultural heritage of the people (e.g., Lake Bosumtwi is a sacred lake of the Ashanti people of Ghana; see Rattray [1923])

There are also plans to build a crater museum at the crater rim to boost tourism in the area. Unfortunately, the plans to build the museum have not measurably progressed during the past years, even though funding assistance with the design of the scientific exhibits, and with exhibits themselves, was pledged by the ICDP drilling project.

The tourism industry could be an alternative livelihood for the communities around Lake Bosumtwi that currently depend heavily on farming and fishing. To the communities and local authorities of the Lake Bosumtwi basin, development of tourism could be important for employment generation, as a contribution to government revenue, for the improvement of infrastructure, and for individual and corporate income generation.

ECOTOURISM DEVELOPMENT PLANS

Ecotourism is a subset of sustainable tourism, differing by its focus on ecology. As defined by The Ecotourism Society (www.ecotourism.org), ecotourism is “responsible travel to natural areas that conserves the environment and improves the well-being of local people”; it is about connecting conservation, communities, and sustainable travel. This involves observing the following principles: minimize impact build environmental and cultural awareness and respect, provide positive experiences for both visitors and hosts, provide direct financial benefits for conservation and benefits and empowerment for local people, and raise sensitivity to host countries’ political, environmental, and social climate.

In order to make ecotourism successful in the long term at Lake Bosumtwi, a Lake Bosumtwi Development Committee was formed by the Ashanti Regional Coordinating Council (ARCC) in 2000, with the backing of the Ashanti king and the Ghana government. This committee aims to ensure that local people are empowered to make use of their own abilities. Ecotourism can be developed according to socially responsible, economically efficient, and environmentally viable guidelines to foster a constructive dialogue about indigenous needs in terms that are understandable to the locals (e.g., Prakash et al. 2005; Wiggins et al. 2004). For this reason, there has been an increasing interest in planning and designing ecotourism projects and controlling how they evolve in the area.

DISCUSSION

Among the well-preserved impact structures on Earth, Bosumtwi is outstanding because of the wealth of data accumulated (e.g., Koeberl and Reimold 2005) during the last 10 years or so of intense research work that culminated in the ICDP drilling project (e.g., Koeberl et al. 2007). Bosumtwi is also the only significant natural lake in Ghana, and is relatively easily accessible. The infrastructure available in
nearby Kumasi (in terms of air and road access and hotels), as well as accommodation facilities available at or near the lake, have led within the past few years to an increase in local (Ghanaian) tourism in the Bosumtwi area. If a crater museum similar to those at Meteor Crater, Ries, or Tswaing could be built at or near the crater, and if it were properly advertised not only in national, but also in international sources, it is conceivable that such a museum would provide an additional attraction for the Bosumtwi region, leading to an increase in dedicated “crater tourism.”

There are also plans to make Bosumtwi a UNESCO World Heritage Site, because it is probably the best-preserved young complex meteorite impact crater on Earth, and its unique and attractive location in a partly original forest region makes it a prime geological site in Ghana. In addition, the lake is a sacred place for the traditional communities of the Ashanti region in Ghana. The Ashanti consider Lake Bosumtwi to be a god. There are several sacred sites around the lake that are of cultural importance to the people in the Ashanti region (see, e.g., Rattray 1923) that could serve as tourist attractions (see also http://people.freenet.de/bosomtwe/backgroundinfo.html).

As mentioned above, the fishing and farming activities around Lake Bosumtwi cannot be sustained indefinitely. Thus, tourism in the area is being looked at as an alternative means of income for the people. The problem now is how to address the environmental issues, especially with regards to the pollution of the lake. At the moment, there is no agency that acts as a watch-dog for the lake. The Unit Committees (officially representing the District Assembly in the community; their major tasks are development, sanitation, and by-laws) could be important players in this regard, who could ensure that the environmental laws are followed by community members. Well-maintained waste bins at vantage points around the lake basin would also be helpful. Currently some refuse dumps around the lake are overflowing and waste is washed into the lake during rainfall (Prakash et al. 2005, p. 27). Also helpful would be to educate local people about the negative effects of bathing, washing, and cleaning in the lake with soap and detergent, but of course alternative means (e.g., public showers that are connected to a proper waste-water system) would have to be provided. In fact, using soap in the lake is already prohibited, but very few, if any, fines have ever been issued (Prakash et al. 2005, p. 25). Furthermore, education on the use of livestock droppings as organic manure for farming should be intensified. In this case, the amount of manure that will eventually be washed into the lake as runoff would be minimized. Wherever possible, nutrient-capturing vegetation should be planted along the lake shore to act as a natural barrier against nutrient influx into the lake. As noted above, a first step in helping to protect and preserve Lake Bosumtwi was the establishment (in early 2006) of a 10 km wide buffer zone around the lake, within which mineral exploration and mining activity is prohibited. Ecotourism development in the Lake Bosumtwi basin undoubtedly depends to a large extent on the lake. Pollution of the lake water will hinder ecotourism development. For one thing, it will affect the aesthetic beauty of the lake owing to water contamination and dead aquatic life. This would reduce the recreational and tourism value of the lake. For instance, swimming in the lake would become unpleasant or dangerous. Moreover, polluted waters could provide a habitat for waterborne and insect-borne diseases, such as diarrhea, bilharzia, typhoid, cholera, and dysentery.

Ecotourism aims at actively involving local people in planning and management of the facility. Both of these stages also need involvement and efforts from local authorities. Through proper planning, efficient implementation of development and continuous management of tourism, the benefits of tourism to local communities can be optimized and the problems minimized. The advantage is that it provides an impetus to expand tourism development and conservation of the natural resource (Wiggins et al. 2004). The prime areas for nature-based tourism including ecotourism are evidently those that are legally protected, as this offers the best guarantee for maintaining their attractions in the long term (Boo 1992; Ceballos-Lascurain 1991; Wight 1993). The Bosumtwi Forest Reserve, which is near the Ankaase community at Lake Bosumtwi (Fig. 2), and has an area of 140 km², is a legally protected area that consists of semideciduous tropical rainforest and provides a typical natural environment of the sort that attracts ecotourists (for details, see Prakash et al. 2005, pp. 38–39). Environmental education is one of the most obvious benefits to conservation generated by ecotourism (Boo 1992; Ceballos-Lascurain 1991; Whelan 1991). The potential of the industry to educate tourists in order to later involve them in active conservation efforts is well documented by, e.g., Boo (1992), Ceballos-Lascurain (1991), and Whelan (1991).

Construction of a crater museum on the crater rim, with routes for hiking around the lake to observe impact rocks (suevites) and other aspects of the local geology, also has potential for ecotourism. Planning for such a museum has to take into account the success of museums at other impact craters, such as Meteor Crater (USA), Tswaing (South Africa), or Ries (Germany). The ICDP drilling project has promised to provide expertise for the development of a crater museum and its exhibits. The scientific contents of the museum will include some general information on the formation of impact craters, as well as on local and regional effects of medium-sized impact events, on the geology of the Bosumtwi crater in particular, and information on the hydrologic and biologic aspects of Bosumtwi. Thus, it will be of use for the education of Ghanaian and foreign researchers and students (including school children), as well as for the public in general. If properly advertised, if the building and its
CONCLUSIONS

The Bosumtwi impact crater and the lake that fills it are not only of scientific interest, but also have the potential to be important for the development of ecotourism in Ghana. However, problems ranging from pollution (from human, industrial, and agricultural sources) to waste management to infrastructure (e.g., roads, hotels) need to be seriously and immediately addressed. The lake is in a hydrologically closed basin; thus, all pollutants remain in the lake and concentrations will increase in the future. There is, therefore, the need for comprehensive research on the state of the water quality of the lake. No such research has so far been done at Bosumtwi, but would be essential for understanding the status of the lake. Because the lake is the main attraction for ecotourism in the area, it needs protection and conservation, as the decreasing environmental quality of the lake may adversely affect ecotourism development.

The formation of the crater by an extraterrestrial body makes Bosumtwi a unique meteorite crater heritage site in West Africa. While the area surely deserves this title, it unfortunately has not yet received adequate promotion from the Ghanaian authorities. Environmental education is one of the most obvious benefits to conservation generated by ecotourism. The potential of the ecotourism movement to educate tourists and potentially involve them in active conservation efforts is well documented. Apart from the lake itself for recreation and aesthetic values, other areas that
exhibit potential for ecotourism are the remnants of the moist semideciduous forest around the lake, and the exposures of impact breccias outside the crater rim (which, if properly signposted, could be as interesting as similar locations around the Ries crater in Germany), and a crater museum—if it is properly designed, staffed, and maintained. An ultimate goal would be to have Bosumtwi nominated and accepted as a Geopark or a World Heritage site to promote its immense educational and tourism potential. There are so far only two other sites in Africa where meteorite impact structures are protected (the Tsawaing Meteorite Crater Museum and the Vredefort World Heritage Site, both in South Africa). This is a call to the international community, especially the impact scientists, to assist in establishing a crater museum at Bosumtwi and to help lay the foundations to protect this unique geological feature.

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REFERENCES


