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The hydrogeological and cultural background for two sacred springs, Bø, Telemark County, Norway

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ABSTRACT

Of the many sacred springs in Norway, most dedicated to St. Olav, several have disappeared. Two of the sacred springs that still exist are located in Bø in Telemark, Southern Norway, and have been surveyed for their sedimentology and hydrology. The springs are embedded in a cultural landscape with several ancient monuments. The aquifers have been mapped by drilling, monitoring wells, and ground penetrating radar and analyzed by GIS models. The area is at the marine limit and most of the sediments have been deposited in the sea. The aquifer of the first spring occurs in subglacial and submarine sediments covered by a series of moraines. The aquifer of the other spring is above the confining till layer, bounded by moraines and located inside a 20 m thick glacial delta deposit. Both aquifers have documented properties that produce springs which under normal climatic conditions never dry and show stable temperatures close to the yearly mean air temperature. The residence time of the water is long for both of the aquifers. Both springs are point features and are not parts of large seepage faces. The locations of the springs may indicate a sacred position in an area of prehistoric farmland, Iron Age burial mounds, stone monuments of unknown age, and cup mark carvings. The springs are contaminated from old landfills, but are reverting, and one of them is under threat from sand pit expansion.

1. Introduction

This paper presents the hydrogeological and cultural background for two sacred springs in Bø, Telemark, Norway. The subsurface environment in this area has been mapped in detail over several years within the frame of a monitoring program for ground water contamination from an old landfill. Bø municipality is situated in the central parts of the County of Telemark and is located 150 km SW of Oslo and ~50 km north from the coast (Fig. 1). Telemark County reaches from the southern coast of Norway to the Hardangervidda mountain plateau. The central and western parts of Telemark County are carriers of old traditions manifested by medieval stone or stave churches, national costumes, decorated clothes, folk music, and well preserved dialects. The springs are embedded in these traditions. The springs have not been recorded by the Norwegian authorities as sacred springs, but the ancient use of them have been presented by local historians (Nordbø, 1945; Henneseid, 1982).

Large areas of Central Telemark are characterized by permeable Quaternary glaciofluvial deposits from the last ice age containing aquifers. The aquifers developed within these permeable deposits are fed by precipitation and infiltration from streams coming from watersheds of different sizes (Klempe, 1990). Springs are located at outflow areas of these aquifers. Aquifers are also found in the fractured bedrock with outflow areas towards the valley bottom including springs. The aquifers are situated in Quaternary glaciofluvial deposits. Many of these aquifers have outflow areas with springs.

A spring is a place where ground water flows out from the aquifer. It can be an outflow point with surrounding wet area, but more often a spring is part of a larger seepage face (Bear, 1979) which includes a wet area of marsh with a diffuse outflow of water over a larger area. Along this area, there are some points where the water flows out in small rivulets. To date, no one has described the aquifers of Norwegian sacred springs in terms of hydrogeology as background for the properties of the springs, including sedimentology and hydrology. Sedimentology includes the extent of permeable sediments, information on layering, thickness, as well as analysis and theories about formation of the sediments. The

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hydrology comprises calculation of watershed, inflow and outflow areas, groundwater flow pattern, and modeling. The purpose of this article is to present the hydrogeological background for two sacred springs in Bø in Telemark based on subsurface mapping and analysis of the aquifers, and to connect the aquifers and springs to natural and artificial elements in the landscape which may have been of cultural significance for the people living in this area.

2. The two sacred springs

Sacred springs are found all over Norway and have been celebrated from pre-Christian ages, but unfortunately many of them are now lost (Werner, 1998). The two springs in Bø are still there as reminders of the past. The location of the springs is shown in Fig. 2. The outflows of the two springs are at points that are surrounded by very small wet areas located in small hillsides. There is no written documentation that these springs were sacred, but the names of the springs, old folk legends about them, the landscape, and ancient monuments in the neighbourhood give strong indications that these two springs have been sacred. The two springs are Olavsolla and Olavsbekk, and the first parts of their names indicate that they, as most of the sacred springs in Norway, have been dedicated to St. Olav (Bø, 1965). This saint is King Olav Haraldsson who fulfilled the Christianity of Norway. He fell at the battle of Stiklestad in 1030 AD and was declared a saint the year after. Many medieval churches are dedicated to St. Olav. The second parts of the names are local names for springs. *Olla* in Olavsolla is the definite form of *olle* that is a common old name for a spring in Norway, and *bekk* in Olavsbekk is in the Bø dialect synonymous with spring or well. Else bekk is a rivulet. Olavsolla and Olavsbekk can therefore be understood as St. Olav's springs. Olavsolla is situated on the ground of the farm Aagetveit. The word “Aage” in Aagetveit is derived from Old Nordic and may describe a very little pond or sacred place (Henneseid, 1982). Old folk legends (Nordbø, 1945) give the impression that the water from these two springs has been powerful and in a way unusual. The first legend is: “At the farm Aagetveit there is a spring that is quite unique. It always flows with clear and good water and while other springs are filled of ice this spring never freezes and never dries up”. The following legend is also from Aagetveit: “When someone at this farm was to die this person had to get water from the spring Olavsolla”. Folkestad is a large neighbouring farm of Aagetveit, and the third legend is about the Folkestad farmers and Olavsbekk: “On Christmas Eve when they had raised the yule sheaf and drunk the yule dram the farmers at Folkestad rode to Olavsbekk and watered their horses” which, according to Werner (1998), was a common custom in Norway on Christmas Day or Boxing Day.

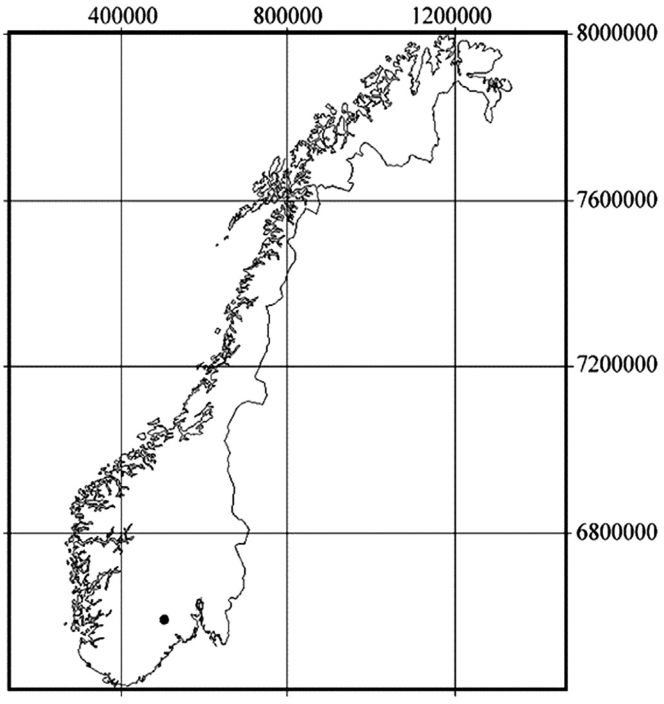

Fig. 1. Location map of the two springs in Norway.

Olavsolla is also close to a bedrock outcrop called Aagetveitberget which may have had significance in the prehistoric landscape. Several monuments inside a radius of 1 km from the springs tell about a landscape where people lived, cultivated the land, buried their dead, and celebrated life and death. Close to the spring a rounded stone with cupmarks was found, but has unfortunately been lost. A low burial mound is found at the top of Aagetveitberget and several low burial mounds are located 400 m from Olavsolla in the area between the two springs (Fig. 3). Around 1 km to the south from the sacred springs are Gaarahaugen and its surroundings with several monuments of prehistoric age, including a long standing stone with a curved sharp edge and a 2.5 m tall menhir (a monolithic stone) (Fig. 4). At Gaarahaugen there was a medieval stave church which was torn down around 1850. About 120 m SW of this arrangement, there are two stones on both sides of a low burial mound (Fig. 5). The southern stone consists of quartzite and the northern stone is of amphibolite where eight carved cupmarks are found (Fig. 6). Close to these stones, five large burial mounds from the Iron Age can be found. From Olavsolla there are views towards the medieval stone church at Bø haugen and the Bronze Age mound at Høyslass, as well as towards the rock formation at Gygrestolen that, according to tradition, has been the chair of the female troll Gygra.

3. Settings

The landscape in Bø is characterized by a circular valley located between Lake Seljord in NW and Lake Norsjø in SE. The valley is surrounded by several hills including Mount Lifjell to the north. The relief is high ranging from Lake Norsjoe at 15 m asl to the peaks of Mountain Lifjell reaching up to 1200 m asl. The marine limit is around 150 m asl and part of the valley was a fjord at the end of Weichsel and during the first 7000 years of the Holocene (Bergstrøm, 1999). The two sacred springs are situated below the marine limit. When the glacier retreated, it stopped at several places due to climate fluctuations and and/or bedrock obstacles that prevented shelf break off. During the ice recession the calving processes in general decreased due to the generally higher topographical level of the inland area. Much ice was then above sea level, and only in the major valleys was it in contact with the sea. Converging ice flows towards the fjord valleys developed with concave calving bays (Bergstrøm, 1999). The glacier can be characterized as a valley glacier (Jansen, 1986). When the glacier was at this particular site melt water streams were running down from the hill- and mountainsides and drained along and beneath the valley glacier towards the outlet at the glacier front. In these glacial melt water streams river deposits accumulated along and beneath the glacier. On the seafloor outside the outlet at the glacier front, submarine sand and gravel accumulated and submarine moraines were formed along the glacier front. Later the moraine complex was covered by a huge glacial delta deposit and marine silt and clay were deposited on the sea floor outside the glacial delta deposit. The aquifers of the two sacred springs are found inside the deposits of the submarine moraine – glacial melt water complex.

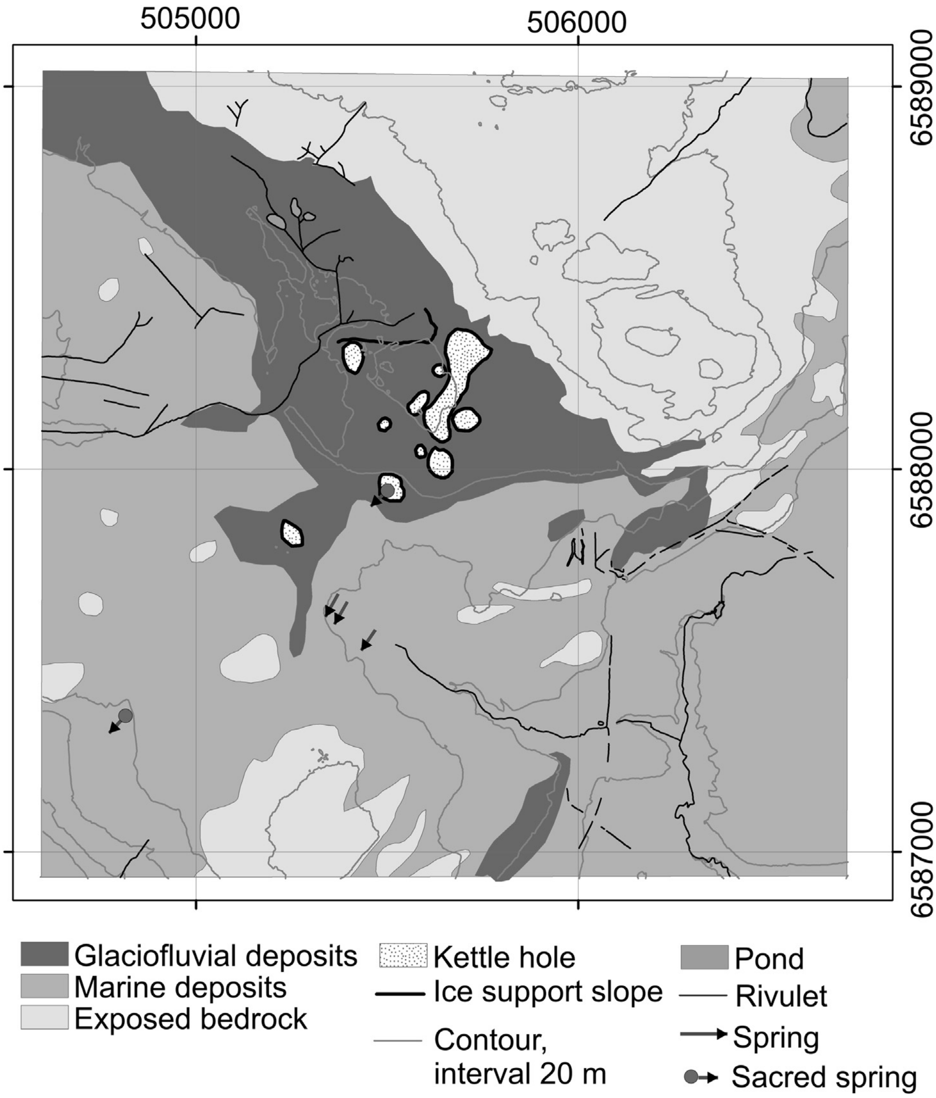

Fig. 2. Quaternary geological map (modified after Jansen, 1980) and the springs.

4. Methods

4.1. Sedimentary units and subsurface bedrock surface

The main boundaries of the Quaternary deposits are given in the Quaternary geological map prepared by Jansen (1980) (Fig. 2). The stratigraphy and the thickness have been mapped by sound drillings, small test wells, borehole drilling, grain size analysis, and GPR (ground penetrating radar). Data from these surveys have been stored in an Access database as lithofacies and sets of specific subsurface lithofacies have been identified by queries in the database (Klempe, 2004). Sets of specific lithofacies are defined as specific sedimentary units. These queried point data were taken into ArcGIS and included in polygons with boundaries from the Quaternary geological map or with probable boundaries of subsurface geological features. Each polygon represents a surface layer of a certain sedimentary unit. Examples are layers from a submarine fan or moraine. One sedimentary unit can occur at several places and levels in the field space. The subsurface bedrock surface is a unit in this system. The topography of each subsurface layer was created by linear interpolation in a TIN (triangulate irregulate network) in ArcMap.

4.2. Hydrological modeling

The watershed and flow accumulation pattern has been modeled by the Hydrologic modeling module in ArcMap. The modeling has been conducted on a raster of cell size 1 m converted from a TIN model created from contours of 1 m interval on FKB data from The Norwegian Mapping Authority 2013. The coordinate system used was UTM WGS 1984 zone 32 N. Yearly catchment runoff was taken from the NVE Atlas (2014). For the Olavsolla aquifer watershed, the yearly runoff is 262 mm/y.

4.3. GPS and map point data

All cultural point features have been georeferenced by GPS measurements or have been taken directly from the FKB map. The GPS device used was a Garmin GPSMAP 62S 2011 model which is a handhelt GPS with a limited precision of 1–4 m. All groundwater observation points have been recorded by a GPS with an accuracy of 1 cm. The point coordinates were established in an Excel spreadsheet and the file was converted to a shapefile in ArcMap.

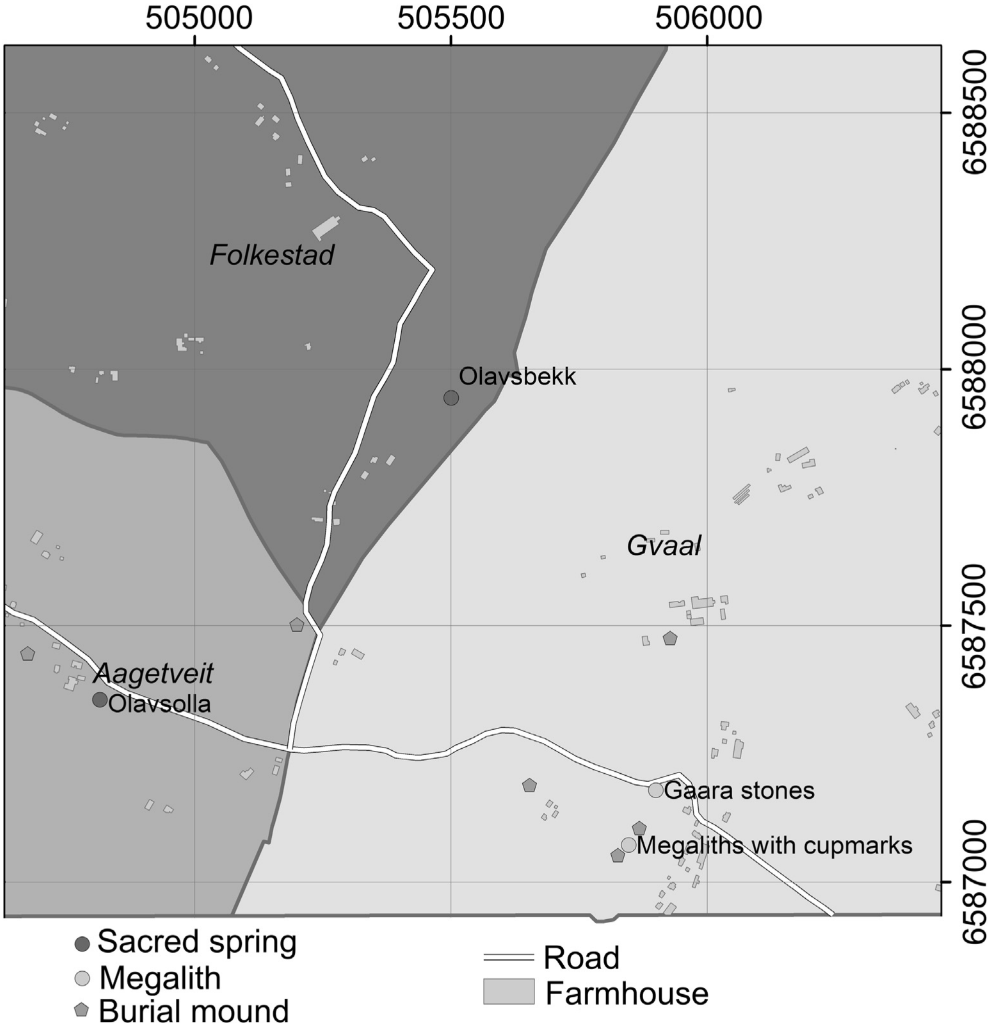

Fig. 3. Map of the sacred springs and their surroundings including farm names, Gaarahaugen with the stone monuments and burial mounds.

Fig. 4. The standing stones at Gaarahaugen.

Fig. 5. The two grave stones close to Gaarahaugen.

4.4. *Pumping tests and soil sampling*

Transient pumping tests have been performed in the middle of the aquifer, using a 5 cm screened pumping well, and seven sets of multilevel piezometers each with two or three piezometer levels. All pumping tests were done until stationary conditions were obtained. Soil samples have been taken from air blown soil from well drillings or pumped water from small test wells.

4.5. *Ground water discharge and flow*

The ground water table and ground water flow pattern are deduced from manual interpolation of contours and mathematical modeling in Watflow (Molson and Frind, 1993) and FEflow 5.2 (WASY, 2006). Discharge, velocity, and travel time for horizontal flow have been calculated by Darcy's law for confined aquifers.

$$Q = K{*}i{*}A\left(m^3/d\right) \quad (\text{Bear, } 1979)$$

Where K = hydraulic conductivity (m/s)

i = potential head gradient

A = cross sectional flow area (m^2)

The calculations are based on potential head gradient (i) and cross sectional flow area (A (m^2) from map data and values for transmissivity T (m^2/d) and hydraulic conductivity K (m/s) from pumping tests and grain size distributions. The transmissivity T was calculated by Jacob's method for confined aquifers under transient conditions (Kruseman et al., 1991). Hydraulic conductivity K was calculated from grain size distributions by the method of Beyer and Scheweiger (Languth and Voigt, 1980).

4.6. *Chloride water sampling and analysis*

Chloride analyses from 1998 to 2013 are available from the monitoring program for the landfill contamination. To calculate the residence time through the aquifer towards Olavsolla coherent peaks of Cl concentrations from one of the monitoring wells and Olavsolla were selected.

Fig. 6. Cup marks on the amphibolite grave stone.

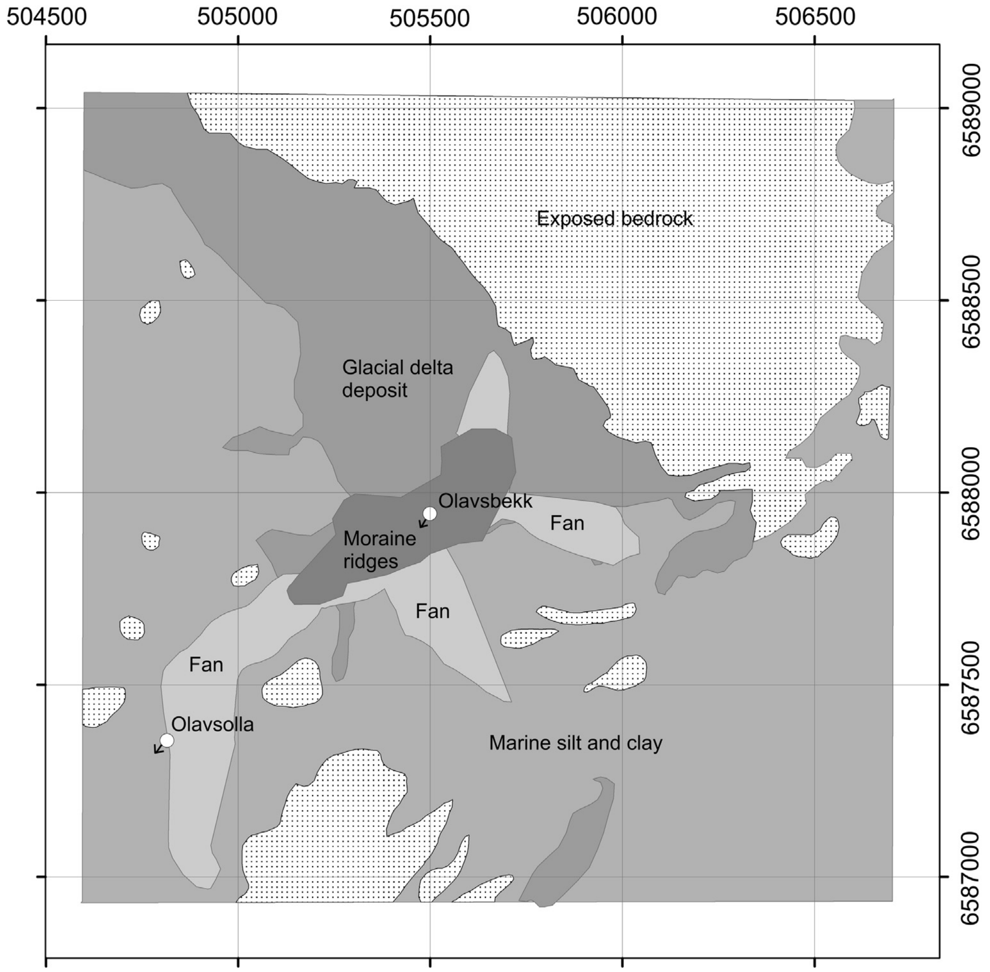

Fig. 7. Map of the subsurface geological formations and submarine fans.

Fig. 8. The sacred spring Olavsbekk.

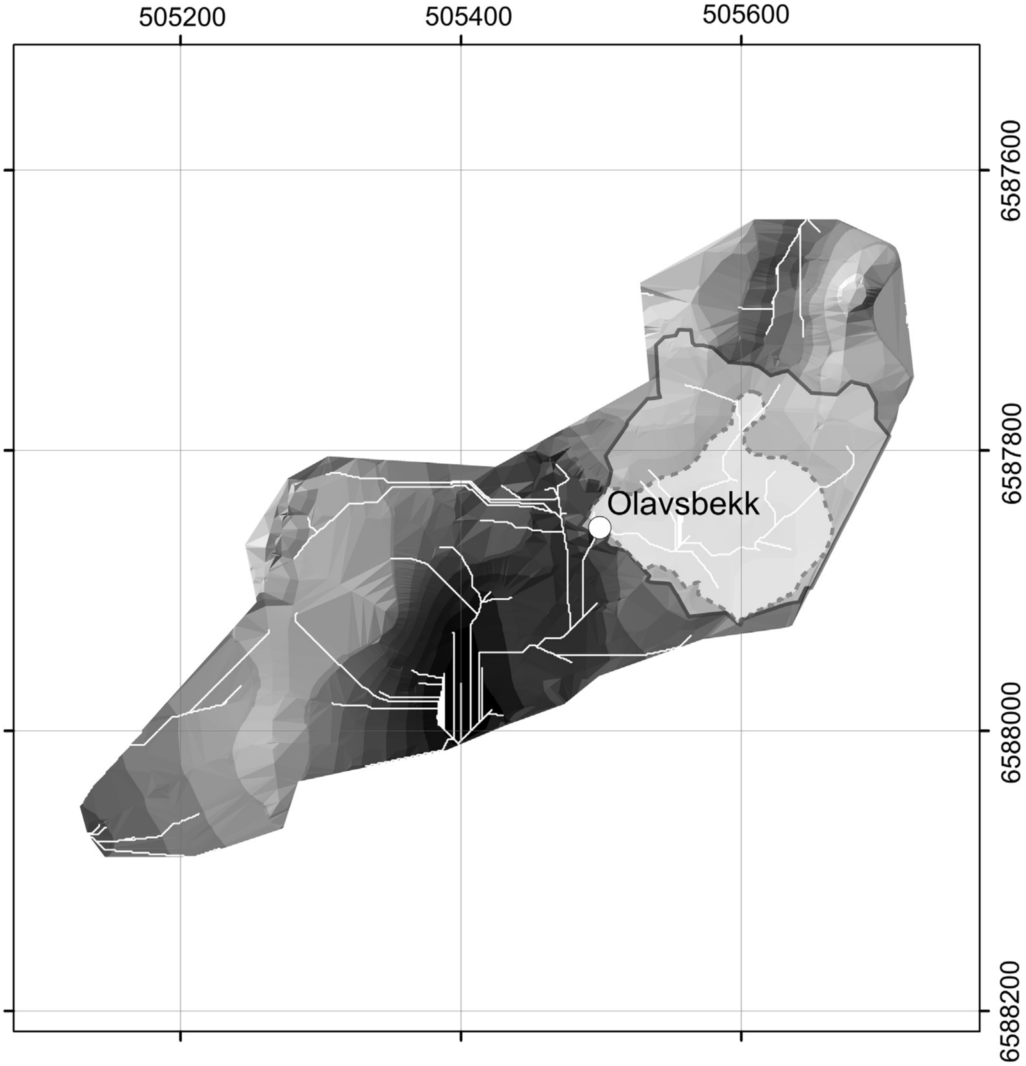

Fig. 9. The sacred Olavsbekk aquifer with watershed and the moraine ridges.

Fig. 10. The sacred spring Olavsolla with views towards three important landscape elements. From the left Gygrestolen, the Bø medieval church, and the hilltop Høyslass with the Bronze Age burial mound.

5. Results

5.1. Sedimentary model and aquifers

The two sacred springs' relation to the Quaternary geology is shown in Figs. 2 and 8. Olavsolla is flowing out from a point in marine deposits of silt and clay and Olavsbekk is located as a small pond in a kettle hole in glaciofluvial deposits. The GIS subsurface sedimentary model (Fig. 7) shows an interpretation of the sedimentological features beneath the surface which can be used to explain the springs' locations. Olavsolla is an outflow point from an aquifer comprising a subsurface complex of moraines and subglacial waterlain sediments. The framework is given by the following five geological formations, from bottom to top: bedrock surface, lodgement till, subglacial/submarine fans, moraines, and glacial delta deposits. In the eroded bedrock surface, a cleft trends SW. Three end moraines have been identified, with grounding lines at both sides of the cleft. Melt water from the ice was flowing in subglacial tunnels running parallel and close to the longitudinal margin of the valley glacier in the NE direction. Close to the glacier front, the subglacial river network joined to from one channel running nearly 90° to the SW running cleft. The top of the tunnel was slightly above the sea level and the rivers were running in a submarine position. The river crossed the cliff at the cleft margin with a waterfall of around 25 m and then turned westward and followed the cleft as a subglacial/submarine current. This river was running over exposed bedrock and till and left one long subglacial deposit and two smaller submarine fans. The subglacial channel was nearly parallel to the glacier front and at two places along the front outlets from gaps between the glacier and the ground opened for sediment-bearing melt water streams to flow into the basin producing submarine fans of gravel and sand. The overall picture is a long subglacial deposit of sand and gravel with a thickness between 5 and 8 m and a width of 70–100 m connected to two branches of submarine fans by a thickness of 20 m. The subglacial channel deposit is covered by a moraine complex. The terrain model of the moraine surface produced three moraine ridges (Fig. 9) from three different ice positions. After a retreat of the glacier, there was an advance and a till plain ending in a moraine ridge was formed. A new retreat followed with new advances, and two other moraines were created. These moraines and till cover the entire subglacial channel and are the confining layers of the aquifer feeding Olavsolla. From the last glacier position, a glacial delta deposit was built and covered the moraine complex. The thickness of the glacial delta deposit is 10 m above the moraine ridges and 20 m in the valley between. The moraine complex and the covering glacial delta deposit comprise the watershed, the unsaturated zone, and the phreatic aquifer feeding Olavsbekk.

5.2. The confined aquifer feeding Olavsolla

Olavsolla flows from a confined aquifer located in the subglacial deposit beneath the moraine complex (Fig. 10). It is fed by a small watershed (Fig. 11). The modeled flow accumulation pattern inside the watershed shows that the runoff is entering the aquifer at one point at the upper end of the aquifer. It is not known if there are gaps between the till and the bedrock surface for other input fluxes along the moraine ridge. Water flows through the aquifer towards four outflow areas. The first two outflow areas are at the ends of the two subaquatic fans. From these outflow areas, rivulets flow year round. The third outflowing point is at Olavsolla and the fourth is at Helland. Total discharge from the catchment area is calculated to be 92 m^3/d. Mean transmissivity from the pumping test is $T = 3.9*10^{-3}$ m^2/s giving a daily runoff from Olavsolla of 35 m^3/d which is about one-third of the total inflow. Mean residence time from the chloride observations for the years 1998–2012 is 2 years and 6 months (923 ± 80 days). From this residence time the ground water flow velocity is calculated to be 1.3 m/d. The average storage coefficient S from the pumping test is 10^{-4}. The fourth outflowing area at Helland is at the end of the confined aquifer where a huge seepage face produces a rivulet that is flowing towards the Bø River. A discharge test was done here after a long dry period by filling a bucket over time. The result was 27 m^3/d, which verifies the calculated runoff value.

5.3. The phreatic aquifer feeding Olavsbekk

Olavsbekk is located in a kettle hole in the glacial delta deposit (Figs. 2 and 8). This phreatic aquifer is developed in the glacial delta deposit in the depression between two moraine ridges (Fig. 9) and it is assumed that there are no confining layers in the glacial delta deposit. The till represents the bottom of the aquifer. Infiltrated precipitation at the delta deposit surface is the only source for ground water recharge. The watershed is small and the travel time for the groundwater is short. Water balance studies in this area (Klempe, 1989) have shown that around 50% of the average annual precipitation of 800 mm infiltrates. The same was found by Jørgensen and Østmo (1990) at the Oslo Airport. From this finding it is calculated that average runoff from the spring is 30 m^3/d. The groundwater flow velocity is calculated to be 0.86 m/d and the travel time is thus 140 days or shorter since this is a phreatic aquifer. The thickness of the unsaturated zone is calculated to be 21 m.

5.4. Properties of the two sacred springs

The two investigated springs may have been sacred because of their location, water properties, and because they are distinct point features with outflow of water from the ground, not parts of wide seepage areas. It is documented (Nordbø, 1945) and from recent observations that Olavsolla never freezes. Olavsbekk is, however, in wintertime covered by snow and ice. The surrounding kettle hole at Olavsbekk has a very specific shape like an amphitheatre which probably made this a unique site for ancient people. A similar shape, even though not so pronounced, is also present around Olavsolla. Folklore traditions state that the water from Olavsolla had a good taste (Nordbø, 1945). Since 1998, Olavsolla has been included in the monitoring program for leachate contaminated aquifers. Values high above the background values of chloride, ammonium, and nitrate from 1998 indicate contamination from the landfill, and lowering of chloride and ammonium concentrations and steady values of nitrate over years after the closure of the landfill in 1997 verify this. In 1989, Olavsbekk had a pH ~6, an electric conductivity of 239 μS/cm, and high chloride concentration indicating contamination from an old landfill in a kettle hole that was closed in 1974.

6. Discussion

O'Dochartaigh (2000) wrote that hydrogeologists should include in their survey not only the scientific analysis, but also local names given to wells and springs. It may be characteristic for hydrogeological presentations that, although O'Dochartaigh (2000) emphasized the need to combine the scientific and cultural aspects, most of the chapters in Robins and Misstear (2000) are not such combinations but products of specialists. The book on Groundwater

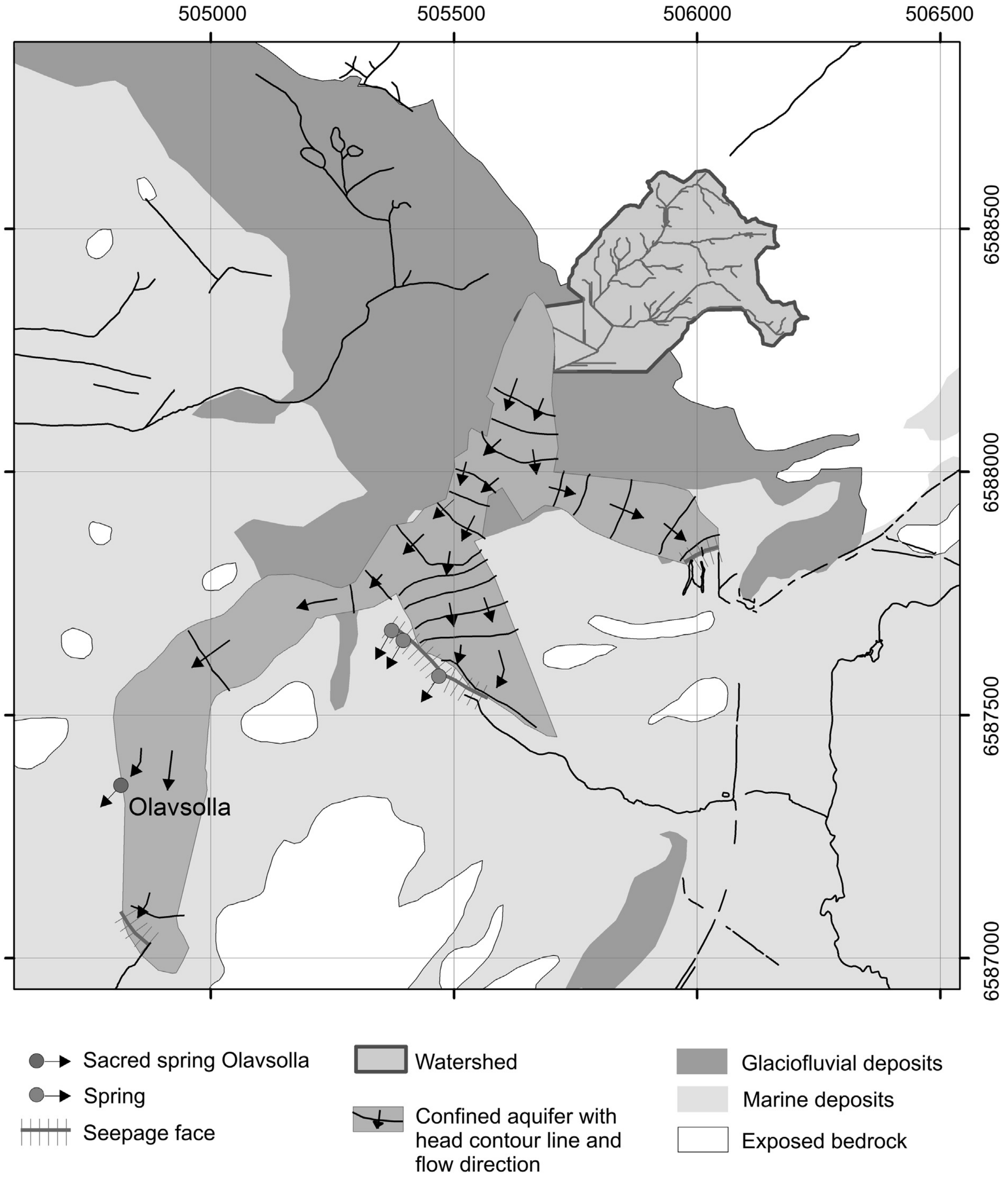

Fig. 11. The Olavsolla aquifer with watershed and outflow areas.

Hydrology of Springs (Neven and Stevanovic, 2010) concerns scientific issues. Prehistoric archaeology has, on the other hand, not included springs and water as important elements in monument landscape settings and has just briefly mentioned them: e.g. Nash (2006) about Welsh chambered tombs and Pearson (2012) and Burl (2007) about the river Avon and Stonehenge. It has been a challenge of this work to include old names, folklore legends, and the surrounding landscape with stone monuments and ancient farm regions. This should close the gap between the scientific analysis of hydrogeology and the spring's role within the ancient societies and landscapes.

6.1. *Sedimentology*

The pattern of submarine sediments that is found in this area is unusual for Norway. A common model around the marine limit is a glacial delta deposit ending in marine deposits of clay and silt with an aquifer filling up the permeable space up to a certain level governed by the water balance. In this case, the space in the glaciofluvial delta deposit is occupied by moraines and the small Olavsbekk aquifer.

Submoraine aquifers are not frequently observed in Norway. The Quaternary superficial map (Jansen, 1980) indicates that the grain size of some of the marine sediments is sand or gravel. These areas are submarine fans and the sediments have been deposited close to the glacier front. This also explains the huge ground water outflow at the seepage faces that are at the end of these marine sediments. The kind of ground water outflow that would be expected here is a seepage face with springs at the foot of the distal part of the delta, which is not the case. The sedimentology therefore governs the occurrence of aquifers and the outflow areas. The subglacial channel could be similar to the subglacial drainage channels of gravel and sand that have been observed from Denmark (Jørgensen and Sandersen, 2006), from Ontario, Canada (Brennand and Shaw, 1994), and from Wisconsin (Hooke et al., 2006) which all have directions at 90° to the ice front. This channel may look different because the drainage pattern is parallel to the ice front, but all the three outlets are at 90° to the front. As in the drainage channels in Ontario (Brennand and Shaw, 1994) this channel's reach has not been eroded in sediments only but also follows a tectonically created cleft in the bedrock. It can be expected that more subsurface surveys and new interpretations of earlier works will show that these kinds of deposits are more common than previously accepted in Norway.

6.2. Ground water storage and discharge

From the legend about Olavsolla (Nordbø, 1945), it is known that the spring never dried up which can be explained by recharge, storage, and long residence time. The total volume of the aquifer is calculated to be 2,54,000 m^3 by using a width of 40 m and a thickness of 5 m. With a yearly runoff of 30 m^3/d and no feeding from the watershed, the time required for emptying the aquifer would be around 18 years. However, such an emptying would never happen under normal climatic conditions with precipitation events. The relatively constant discharge of the Chalise well in Somerset, England, is explained by outflow from storage (Mather, 2009). There are, however, many other springs or outflow areas in Bø that never dry up completely because they have a large storage of water due to a huge catchment area in contrast to this aquifer's small watershed. The reason for the Olavsolla aquifer's storage capacity is its exceptional length. The aquifer is also confined with a hydrostatic pressure towards the confining layer higher than the atmospheric pressure, so the water level will never drop to the bottom of the aquifer during normal dry periods. The observed residence time of the ground water calculated from chloride concentration observations over 14 years is two years and six months. As far as this author knows, this is the longest residence time in Quaternary deposits aquifers in Bø. This long residence time may have impacted the original quality of the water where the main minerals in contact with the flowing ground water are feldspar, quartz, and biotite. The dispersal of the chloride observation peaks from Fig. 12 can be explained by the fact that the sampling has been conducted only twice or once a year so the observed values are not plume breakthroughs or peaks but rather parts of an extended plume due to dispersion. The dispersion coefficient for such a long distance is around 100 m (Gelhar et al., 1992). The discharge and flow velocity will change over years due to changes in recharge and head potential gradient. During long-lasting rainy periods with large discharge it is possible to see water flowing through the Olavsolla well. The fast response of the ground water flow from precipitation events is due to sudden increase in the head potential gradient when water flows into the confined aquifer from the catchment area. However, during very dry periods the pressure level may drop below the confining layer, and the aquifer becomes phreatic. Then, the spring discharge will be steadier due to a higher storage coefficient and a long flow length. Analytical and numerical modeling results show that discharge steadiness for a spring from a phreatic aquifer of coarse material increases with length of the flow (Swanson and Bahr, 2004).

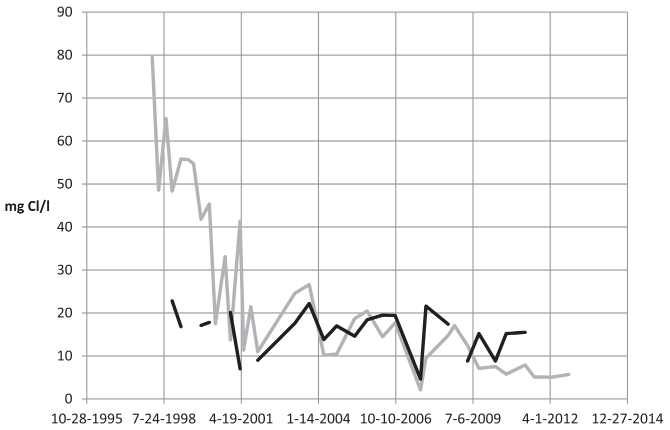

Fig. 12. Chloride concentrations from the Olavsolla over time.

The phreatic aquifer of Olavsbekk will show a different pattern. With an unsaturated zone of around 20 m such a deep-lying aquifer will show small long term water level fluctuations and a steady discharge over time. The aquifer is, however, quite small and it will take around 320 days to empty the aquifer. This would be an unusually long dry period, which suggests that the spring never has dried.

6.3. Ground water temperature

It is also known from the legend about Olavsolla (Nordbø, 1945) that the spring never froze. Groundwater is known to have a stable temperature (Freeze and Cherry, 1979) with relatively cold water in summer and temperatures above zero during winter (NVE, 2014b). Observations from the nearby observation station Eikamoen (NVE, 2014a) show an amplitude difference of 1.7 °C for the year 2013/14 with a maximum value of 7.1 °C reached in December 2013 and a minimum value of 5.4 °C from June 2013. The groundwater level is around 6 m below ground surface. This produces a gently curved trend of temperature over time, with maximum in winter and minimum in summer. The average ground water depth in the Olavsolla aquifer is around the same as at Eikamoen (NVE, 2014a) so the same temperature pattern is to be expected, with temperatures during winter months slightly above 6 °C and in summer months slightly below 6 °C. One other reason why the spring does not freeze is that the water is flowing. The other spring aquifer Olavsbekk has a thickness of 20 m of the unsaturated zone and should show completely stable temperature all year round, slightly above the average air temperature (Freeze and Cherry, 1979; Johnson, 1980). However, because the spring is a pond with an underground drainage and probably with a clogged bottom, it is often covered by ice.

6.4. The sacred landscape and the springs

Water is significant in religious rituals and beliefs all over the world (Håland, 2009) so the described case of sacred springs is a common human phenomenon. As with holy wells in Ireland (Foley, 2011), both natural and manmade elements are included. In this case, the sacred landscape consists of the two springs, the seepage face with the steady state rivulet, moraine ridges and bedrock outcrops, views, the four burial mound areas, the stone monuments, the boundary between two Neolithic territories, and the farmland with temporary settlement to early Bronze Age and permanent settlement from younger Bronze Age. The Iron Age castle to the east may also be included. Mikkelsen (1989) assumes that the farm boundaries that we find in Telemark today were drawn in Late Neolithic. Tilley (2009) has refined this statement with an example from Bodmin moor, Cornwall, where Late Neolithic boundaries were drawn between water, marsh, and rocks on a local scale while late Bronze Age boundaries were drawn as more continuously straight lines over longer distances. The boundary between the two territories has been drawn between Olavsolla and Olavsbekk and the seepage rivulet (Fig. 3). People have lived, worked, and buried their dead inside this sacred landscape with the water as a central element. In Britain, most of the springs are dedicated to national saints (Bord, 2008), while in Norway they are dedicated to St. Olav. The more than 3000 holy wells in Ireland are dedicated to several national saints (Foley, 2011). The widespread use of the name of St. Olav indicates his significant influence in Norway. At Acropolis in Greece, two sacred springs are dedicated to Virgin Mary and are called the Life-giving Spring (Håland, 2009). In the caves with the springs are icons of Virgin Mary (Panagia) and the child (Håland, 2009: 88). These two springs are today still celebrated and the holy water is used for baptizing, washing, drinking, and collecting in bottles. Sacred springs all over Greece have been used from ancient ages through antiquity with celebration of nymphs and different gods (Håland, 2009). Springs, rivers, and inland water bodies are crucial elements of the sacred Greek landscapes (Gerten, 2008). Through Christianity the celebration turned towards Virgin Mary and the child (Håland, 2009). It is a celebration of life and fertility (Varner, 2009). However, there is also a profane aspect; in 1883 the holy water was reinvented as a national symbol for the established Greek nation state (Håland, 2009). As with the Greek springs, Olavsolla and Olavsbekk have been treated as sacred springs over several millennia. For the farming society they have been sacred from the Neolithic probably changing name to Tor springs (Werner, 1998; Rudolph-Lund, 2010) from around 500 AD and to St. Olav springs from 1030 AD. Tor was a Norse god for the peasants. There was a sudden change in religion from 500 AD where votive offerings in marsh and water ended and the Norse religion took over (Fabech, 1994;; Näsman, 1994; Steinsland, 2000: 78). The Virgin Maria springs in Cornwall are still celebrated with pieces of clothing on the surrounding trees (Varner, 2009) which is also common elsewhere in Cornwall, in Dorset, and parts of Wales (Holy and healing wells, 2014). This cannot be seen in Norway any more probably due to the Norwegian Protestant Church which fought Catholic cultures from 1644 (Bø, 1965; Werner, 1998). In Ireland, spring celebration decreased as late as the 1850s due to the church's action for more cultural power (Foley, 2011). The mentioned springs have over ages been celebrated for fertility, life, and death. From ancient Greece, the travelling historian Pausanias 120 AD described several karst holes of sacred water (Clendenon, 2009). In Argos, tree spoons were used to find the velocity of the ground water movement through the karst network (Crouch, 2004). According to Pausanias, the reason why the ancient Greeks could know about the connection between inflow and outflow of karst water was because sacrificed items and animals followed the ground water flow and appeared in the outflow caves (Clendenon, 2009). Many ancient Greek cities depended on karst springs as their drinking water supply (Crouch, 1996, 2004) and the Hebrew city Jerusalem was located at its current place because of the karst spring of Gihon (Amiel et al., 2010). There is therefore a clear connection between a sacred well and a supply well, and the groundwater outflow inside the study area was crucial for crops and drinking water supply and, at the same time, sacred. At Acropolis in Athens standing water in karst caves has been (and is still) regarded as sacred water, the Life Giving Water (Håland, 2009). Olavsbekk is a water filled hole that may be regarded in the same way because the European people have the same Neolithic heritage (Champion et al., 2009). Both of the springs are distinct points in the terrain and are not included in huge seepage faces. Olavsolla flows from a point in marine clay sediments in an unusual manner.

The springs are today under threat. The water quality of Olavsolla has changed due to contamination from the landfill. However, due to dispersion the water quality has always met Norwegian standards for drinking water (Drikkevannsforskriften, 2004). The values are lowering, and over time the natural water quality will be recovered. In the neighbourhood of Olavsbekk a sand pit is planned and will soon start up. This will reduce the unsaturated zone of the aquifer and, in the worst case, destroy the aquifer if all sand and gravel from the glaciofluvial delta deposit is removed. The spring itself and the coherent kettle hole are, however, on a property that is close to but outside the planned sand pit area. In addition to the two sacred springs, there is a huge seepage face in this area where a year-round flowing rivulet runs through the field past the monuments and farm land at Gaarahaugen. The ground water outflow has been the only water support for the entire community at this place over millennia from prehistoric times to today. It could still serve as major support if it would not have been contaminated by the landfill.

7. Conclusion

The two sacred springs Olavsolla and Olavsbekk from Bø in Telemark are among the sacred springs in Norway that have survived and are still flowing in the same way as they have been doing through millennia. The water quality, however, has changed due to contamination from a now closed landfill but is reverting towards a natural water quality. From the Olav names it is assumed that the springs are sacred because most of the sacred springs in Norway were dedicated to St. Olav. The two springs have quite different origins; both are exceptional and depend on the sedimentological formations that were created at the glacier front at the end of the last ice age. The Olavsolla spring is from a confined aquifer, 1.7 km in length, in a subglacial channel covered by a moraine complex. The residence time is two and a half year which is the longest observed residence time of aquifers in this area. The Olavsbekk spring is from a small phreatic aquifer inside a glaciofluvial deposit dammed by a moraine ridge complex. The steadiness of the Olavsolla spring is mentioned by a local historian, and despite their small watersheds neither of the springs will become dry under normal conditions because of their storage, flow length, and thickness of unsaturated zone. The temperature in both springs will always be around the mean air temperature because of the observed depth of the aquifers. The springs are situated inside prehistoric farmland, have views towards special landscape features, and are surrounded by Iron Age burial mounds and prehistoric stone monuments. The detected properties of the springs and the historical and prehistoric surroundings confirm that the springs were sacred springs.

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