



# Provenancing of unidentified World War II casualties: Application of strontium and oxygen isotope analysis in tooth enamel



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## ARTICLE INFO

### Article history:

Received 12 December 2013

Received in revised form 4 February 2014

Accepted 12 February 2014

### Keywords:

Strontium

Oxygen

Isotopes

Enamel

Provenancing

World War II

## ABSTRACT

In 2010 and 2012 two sets of unidentified human remains of two World War II soldiers were recovered in the area where the 1944–1945 Kapelsche Veer bridgehead battle took place in The Netherlands. Soldiers of four Allied nations: British Royal Marine Commandos, Free Norwegian Commandos, Free Poles and Canadians, fought against the German Army in this battle. The identification of these two casualties could not be achieved using dental record information of DNA analysis. The dental records of Missing in Action soldiers of the Allied nations did not match with the dental records of the two casualties. A DNA profile was determined for the casualty found in 2010, but no match was found. Due to the lack of information on the identification of the casualties provided by routine methods, an isotope study was conducted in teeth from the soldiers to constrain their provenance. The isotope study concluded that the tooth enamel isotope composition for both casualties matched with an origin from the United Kingdom. For one of the casualties a probable origin from the United Kingdom was confirmed, after the isotope study was conducted, by the recognition of a characteristic belt buckle derived from a Royal Marine money belt, only issued to British Royal Marines, found with the remains of the soldier.

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## 1. Introduction

The use of strontium ( $^{87}\text{Sr}/^{86}\text{Sr}$ ) and oxygen ( $\delta^{18}\text{O}$ ) isotope analysis in tooth enamel has been extensively applied within the archaeological sciences for the determination of place of origin of our human ancestors [1,2]. Recently, isotope geochemistry has begun to be applied to human tissues (i.e. hair, bone, teeth.) within a forensic context. The techniques are used to provide forensic intelligence to guide law enforcement units in case investigations to determine the place of origin of unidentified modern humans [3–5].

The  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{18}\text{O}$  values in tooth enamel record the isotope signatures of food and drink ingested during childhood. In turn, the  $^{87}\text{Sr}/^{86}\text{Sr}$  ratios recorded in food (i.e., vegetables, fruits, meat, etc.) and drinking water document the isotopic signature of the bio-available Sr of the environment (i.e. soils, water, geology) from where the product originated. The  $\delta^{18}\text{O}$  values in tooth enamel record the integrated  $\delta^{18}\text{O}$  value of ingested food and drinking water. In humans, the  $\delta^{18}\text{O}$  values

in teeth are strongly controlled by the composition of drinking water, which in turn is generally linked to the local meteoric water [6,7].

In this study we present  $^{87}\text{Sr}/^{86}\text{Sr}$  and  $\delta^{18}\text{O}$  isotope data from tooth enamel from two sets of unidentified skeletal human remains (Fig. 1) recovered from the World War II 1944–1945 battle field in Kapelsche Veer bridgehead, near Waalwijk in The Netherlands (Fig. 2). These remains were recovered in late 2010 and early 2012 during explosive ordnance clearance. They were remarkably well preserved as they were buried in river clay laid down by parts of the river Maas system. The aim of the study is to determine the geographical place of origin of the casualties as part of a concerted effort to identify the individuals and lead to their repatriation for burial.

## 2. Historical background

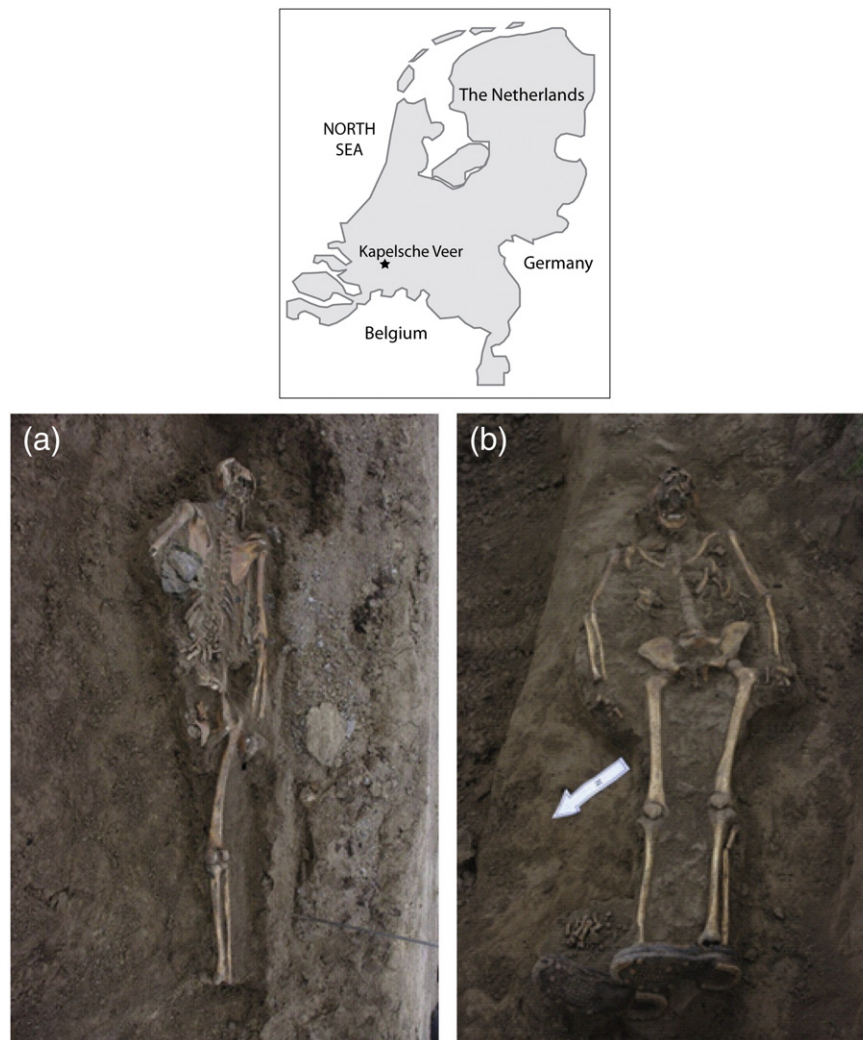
From the location of the remains, the missing in action (MIA) were considered to be related to a notorious series of engagements that occurred between December 1944 and February 1945 at Kapelsche Veer. At this period in World War II the German army had retreated across the Maas to fortified positions with the aim of preventing the Allies from crossing the Maas and Rhine. Their second goal was to counter attack in an attempt to cut the Allies' over-extended lines of communication that stretched from the Normandy beaches to the Scheldt.

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**Fig. 1.** Casualties WW2\_024/12 (a) and WW2\_025/10 (b) found in late 2010 and early 2012 recovered from the World War II 1944–1945 battle in Kapelsche Veer bridgehead, near Waalwijk in the Netherlands.

Kapelsche Veer was a small harbour on the north side of a segment of low-lying land between the main course of the River Maas and the much narrower Oude Maasje (Old Little Maas) referred as the ferry island. In 1944–1945 the ferry island was snow covered, very flat, open and treeless and mostly boggy. It was held by the German 6th Parachute Division. Some historians consider that the successive Operations Trojan, Horse and Elephant, undertaken in order to liberate the German bridgehead should not have been undertaken or at least better planned. The small ferry-port had been used as a bridgehead to support the Ardennes Offensive (Battle of the Bulge) that aimed to capture Antwerp and cut through the Allies' extended supply lines. After the Ardennes offensive had failed, German Luftwaffe General Kurt Student decided to maintain the Kapelsche Veer bridgehead as a means of providing his many young and inexperienced soldiers with some much needed battle experience. Consequently, Allied command had ordered its capture. Kapelsche Veer had been converted into a formidable fortress of extensive zig-zag trenches reminiscent of the trenches of WW I, with a profusion of individual one and two-man weapon pits in the fields beyond this complex defence system. In the dykes nearby were bunkers almost impervious to shells of even the heaviest calibre.

In the successive engagements, soldiers of four Allied nations fought against the German forces: British Royal Marines, Free Norwegian Commandos, Free Poles and Canadians. The first Allied attempts to take

Kapelsche Veer were undertaken by a platoon from the 1st Squadron of the 3rd Polish Infantry Brigade (3 Brygada Strzelców) on December 31st 1944 and again on 7 January 1945, both times without success. The 47th Royal Marine Commando and the 5th Troop of the 10 Interallied Commando that comprised Norwegians, under Polish command, also unsuccessfully attacked on 13 and 14 January (Operation Horse). Finally, on January 26th the 4th Canadian Armoured Division (Lincoln and Welland Regiment, assisted by the Argyll and Sutherland Highlanders and South Alberta Regiment tanks) mounted Operation Elephant against the position with large artillery support, tanks and 60 canoe commandos. After five days of fighting in icy conditions it was reported that all enemies south of the Maas had been cleared. The Germans had lost with 145 killed, 64 wounded and 34 prisoners while the remainder had been evacuated across the Maas. The Canadians had suffered 234 casualties, of whom 65, including 9 officers, were fatalities. After the war the commander of the 6th German Parachute Division said that the defence of Kapelsche Veer had cost him between 300 and 400 serious casualties plus 100 more men disabled by frostbite. In all, nearly 1000 men on both sides were killed, wounded, captured or went missing in the series of engagements at Kapelsche Veer [8].

In summary the MIAs could potentially be of British, Canadian, Norwegian or Polish nationality. Subsequent research, however, established the complication that all nationalities wore British made uniforms and used British issued equipment. The recovered

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