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THE DATING OF DOLOMITIC MORTARS WITH UNCERTAIN CHRONOLOGY FROM MÜSTAIR MONASTERY: SAMPLE CHARACTERIZATION AND COMBINED INTERPRETATION OF RESULTS

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ABSTRACT. To obtain scientific data regarding the chronology of archaeological structures, lime mortar radiocarbon dating has often demonstrated to be a decisive method. However, knowing the specific chemical-mineralogical characteristics of mortars can help when preparing samples or interpreting results. Among other issues, the dating of magnesian mortars can be particularly difficult because of the combined slaking, setting and hardening reactions of the calcium and magnesium phases, typical of these mortars. The formation of numerous mineralogical phases depending on reaction conditions adds further complexity to the dating method, which deserves to be studied with further detail. During the project "Mortar technology and construction history at Müstair Monastery" the first experiments in this regard had yielded encouraging results. An additional 4 samples from buildings with controversial chronology, thought to belong approximately to the 9th, 12th, and 15th centuries, were selected, prepared and radiocarbon dated. The data obtained were discussed by integrating preliminary petrographic characterization analyses of the mortars with archaeological information and excavation records. The results opened up new questions about the chronology of the Monastery, clarified the dating of some buildings and provided a better understanding of the potential and limitations of dating dolomitic mortars coming from archaeological context.

KEYWORDS: Mg-lime, mortar, radiocarbon dating.

INTRODUCTION

The convent of St. John in Müstair is a monastic site listed as a UNESCO World Heritage site since 1983. It lies in a strategic position between Switzerland, Italy, and Austria, along one of the most important north-south routes through the Alps. The Via Claudia Augusta, built by the Romans, remained standing until the early modern age (Grabherr 2006). In 774 Charlemagne conquered the Lombard kingdom. According to legend, after his coronation as king, Charlemagne was caught in a snowstorm on the Umbrail Pass and was saved. In gratitude, he is said to have founded the Monastery of St. John. A 12th century stucco statue of Charlemagne in the church bears witness to this. The Monastery became famous in 1894, when its cycle of Carolingian paintings was discovered. This is the largest and best-preserved fresco cycle from the early Middle Ages in Europe. Art historians date them to the first half of the 9th century. The frescoes today cover most interior surfaces, but in the past the Carolingian decorative cycle was covered and then forgotten until its rediscovery in modern times (Goll 2007).

In its 1200-year history, the Monastery has never been completely destroyed, but only partially refitted and rebuilt. Thus, the monastic complex today presents itself as a collection of buildings of the most diverse architectural styles from different periods, complementing each other (Figure 1). The importance of the site made it the subject of more than 50 years of studies and excavations covering the entire area, during which archaeologists collected thousands of

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Figure 1 Plan of the monastery with different colors for the different phases according to the archaeological reconstructions, showing the walls from which the samples were taken.

artifacts, including about 5000 mortar samples. The research project titled "Mortar Technology and Construction History at Müstair Monastery" was developed with funding from the Swiss National Science Foundation (Grant Project number 105211_169411). Its aim was to study the archaeological mortar fragments in order to identify similarities and differences in building materials in relation to origin and use, organization of workers and dynamics of the construction site (Lubritto et al. 2015; Hüglin et al. 2019). In order to achieve this, it was strongly interdisciplinary in nature. Based on the results of the previous intensive archaeological work, which has been extraordinarily well documented, scientific analyses of mortars and plasters were planned.

Preliminary investigations have shown that the mortars were prepared by burning dolomitic limestone, typical of the area (Cavallo et al. 2019). The radiocarbon dating of mortars (Labeyrie and Delibrias 1964; Stuiver and Smith 1965; Folk and Valastro 1976) can be challenging and this is particularly true for Mg-mortars. Indeed, the reactions that occur in the presence of the combined calcium and magnesium compounds typical of these mortars are more complex. In addition, during the firing, slaking, hardening and setting reactions, numerous mineralogical phases are formed depending on the environmental conditions, as for example temperature, humidity, burning time, etc. (Bläuer-Böhm and Jägers 1997). The complexity of the mineralogical phases, sometimes also characterized by low crystallinity, is such that their precise identification is also difficult, and can add further problems for radiocarbon dating (Hayen et al. 2016; Hayen et al. 2017; Michalska 2019). Initial experiments in dating Mg-mortars from Müstair Monastery yielded encouraging results at the beginning of

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the project (Caroselli et al. 2020). After further investigation, at a later stage, 4 more samples from buildings with controversial chronology, attributed through archaeological observations approximately to the 9th, 12th, and 15th centuries, were selected (Figure 1), characterized and prepared for radiocarbon dating. The results are discussed by comparing them with petrographic analyses of the mortars and archaeological excavation records.

MATERIALS AND METHODS

The choice of different mortar samples to be dated was made considering some potential controversies in the attributed dates and the results of petrographic characterization of about 200 samples belonging to different construction phases of the Monastery. Archaeological research at the sites has provided evidence for at least 10 construction phases. Some are well-dated through a combination of stratigraphy, historical records, dendrochronological and ^{14}C dates, others less so. The project focused on the older phases up until the 15th century, which are generally more difficult to date, since there are almost no written records from this period. The first set of samples previously dated and published in Caroselli et al. (2020) belonged to the early Carolingian phase of the Monastery 775–788 AD (sample nr. 6577 and 957). Reliable dendrochronological dates are available for these samples (Hurni et al. 2007) and they were therefore suitable for an initial test of the method. The second set of samples, the subject of this paper, belonged to walls from two phases that had not been dated reliably so far or whose attribution was uncertain from the Carolingian period onward (sample nr. 17879, 16507, 2211, and 18741).

Petrographic analyses made it possible to study in detail the sources of supply of the materials and their use (Caroselli et al. 2019). In particular, dolomitic rocks ($CaMg(CO_3)^2$) were used for the production of the mortar binder (Cavallo et al. 2019). The use of Mg-lime—a combination of magnesium hydroxide and calcium hydroxide- may make the mortar dating procedure more complex (Michalska et al. 2017). The production of Mg-lime does not follow a cycle like high Ca-lime (Eq. 1), and the products of this series of reactions have different solubilities (Diekamp et al. 2009):

$$CaMg(CO_3)_2 \rightarrow CaO + MgO + 2H_20 \rightarrow Mg(OH)_2 + Ca(OH)_2 + 2CO_2 \rightarrow CaCO_3 + MgCO_3 \quad (1)$$

This may have a negative effect on the dating possibilities of the mortars if the sequential dissolution method is used for the preparation of the samples (Hajdas et al. 2017; Hayen et al. 2017).

Polished thin sections were prepared by a specialized laboratory. Polarized Light Microscopy (PLM) on the thin sections was carried out for mineralogical and textural analysis; a Zeiss Axioskop 4.0 Polarizing Light Microscope (PLM) was used and photomicrographs were acquired with a digital camera, and processed with the software Axiovision (Zeiss, release 4.5.1). The more relevant features for mortar dating were observed: binder (structure, color, birefringence, homogeneity), lime lumps (types, internal structures, quantity, and size), aggregate (grain sizes, mineral and rock types present, estimation of the grain size distribution), additions (brick fragments or organic material), macro-porosity and especially secondary calcite, or hydromagnesite fillings of voids.

The binder enriched fraction of the samples was extracted by dry sieving. The samples were crushed avoiding the formation of fine aggregate. The crushed material was vibrated in a series of dry sieves. The fine-grained (ff) 45–63 µm fractions were sorted and homogenized.

For sequential dissolution, 50–100 mg of the mortar powder fraction was digested with 10 mL of concentrated phosphoric acid (85% H_3PO_4). This process is timed, and the purified CO_2 is frozen in liquid nitrogen (LN) sequentially: successive fractions are collected every 3 s (4 fractions per sample in total). The carbon content of each collected fraction was trapped, graphitized (0.2–1 mg C) and measured directly using gas ion source (GIS) if samples contained less than 200 µg of C (Hajdas et al. 2020).

The measured ^{14}C ages of the different fractions of mortar were plotted in a graph in order to evaluate the removal of the dead carbon, geologic component, which is assumed to dissolve at a lower rate (Folk and Valastro 1976; Lindroos et al. 2007, 2018). Calibration of the final evaluated ages was performed using OxCal 4.4 with the INTCAL20 dataset (Reimer et al. 2020). The first fraction is considered the best estimate of ^{14}C ages, and if followed by agreement with the second fraction, that ^{14}C age can be considered the most accurate measure of the moment when the setting reaction occurred (Hajdas et al. 2020).

BACKGROUND

Carolingian Phase I—Church and Courtyard

Samples from the church and the convent buildings, attributable to Carolingian Phase I (buildings in blue in Figure 1) were dated during preliminary tests and published in Caroselli et al. (2020). The sample belonging to the main church (nr. 6577) has no carbonate sand, which made the dating less complex. In fact, the dating provided results consistent with dendrochronology of a preserved wooden beam in the eastern gable of the church, which was felled in the winter of 775/6 (Hurni et al. 2007). In the medieval period, lumber for building construction was usually felled in the winter and processed in the following months (Alcock 2017). This means that the construction of the church was probably completed around 776. The ages of all three later fractions were so consistent that the ages were combined and calibrated yielding 1180 ± 32 BP and a solar age of 729–961 CE.

The second sample (nr. 957) published in Caroselli et al. 2020 was taken from a wall of the convent buildings. The Chapel of the Holy Cross was probably finished in 788 or shortly thereafter (Hurni et al. 2007), and the remaining convent buildings, which are not preserved above ground and therefore did not provide dendrochronological dates, are thought to have been built between these dates (Sennhauser 2013:91–92).

Even though only the lower parts of the walls and the foundations of the convent buildings have been preserved below ground, abundant sampling of the mortars of these walls has been carried out during archeological excavations. Petrographic results of analyses carried out on a selection of these samples showed that the mortars from the convent buildings are very different from those of the church, with a different texture and unsorted carbonate sand. Sample 957 gave dating results that did not agree with the dendrochronological results from the church (slightly older age). Repeated sequential dissolution did not lead to agreement between the results of the first and second preparation. Therefore, this result that anticipated the presumed archaeological dating was initially discarded.

Additions during Carolingian Phase II

Archaeological excavations have shown that between the late 8th and early 10th centuries, after the completion of the Carolingian Monastery, several additions and alterations were made, which have been attributed to a "Carolingian Phase II" (buildings in light blue in Figure 1). These were mainly additions to the southern corridor of the Monastery ("loggia building") and to the church. Sample 17879 was collected from an archaeologically excavated wall, since no standing buildings exist from this phase. It was taken from an uncertainly dated building south of the church, that has been attributed to the Carolingian phase II.

Late Romanesque Phase

At some point in its history, the monastery for men became a Benedictine convent for women. The first mention of the convent dates back to 1157 (Müller 1978: 33). The change must therefore have taken place before this date. Around 1163–1170, Bishop Aeginus of Chur donated the chapels of St Ulrich and St Nikolaus, located within the monastery, to the convent. This was seen as a sign that the entire bishop's residence was being reorganized, converted into a cloister and given to the nuns to carry out their activities. This building became the new center of the convent, while a new bishop's residence was built to the north of the convent, outside the cloister (Boschetti-Maradi 2005). The interior of the church was also renovated: the walls of the three apses were decorated with a new cycle of mural paintings and a life-size stucco statue of Charlemagne, who, according to tradition, founded the monastery, was erected (Goll 2007).

RESULTS

The results obtained through the dating of mortars attributed to the Carolingian and late Romanesque periods are presented in Table 1.

The petrographic results of the sample 17879 showed that the mortar is very different from the samples collected from the other structures attributed to this phase in the southern courtyard (high binder content and carbonate sand), and that it is more similar to samples from the 1st phase of the Carolingian Monastery (Figures 2A and 2B).

Radiocarbon dating was found to be 1367 BP (±22) (Table 1 and Figure 2C and 2D) which provides a calibrated date between 610–758 CalCE (Table 2) and thus predates the archaeological assumptions about the construction of the monastery (between 776–785 CE). As a matter of fact, the only certain dates are the completion of the church around 776 and the completion of the Holy Cross chapel around 785 (dendro date). Archaeological evidence indicates that the monastery walls were built against those of the church, and that therefore the church must be older than the convent buildings (Sennhauser 2013). Other than that, there is no precise information on the construction of the monastery buildings. Complex archaeological observations, divergent results of mortar petrography, and divergent dating do not allow us to draw new conclusions about Carolingian Phase II. In addition, at present it cannot be ruled out that the church and convent buildings were two independent construction sites that may have proceeded in parallel.

Buildings attributed to Late Romanesque phase modifications exhibit bedding mortars with a systematic presence of overburned fragments in all samples analyzed. In addition, several types of limestone that show signs attributable to an incomplete burning process are very common. Lime lumps *sensu strictu* (Elsen 2006) are also frequent and large. This high and significant

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Table 1 Results of radiocarbon dating. Only the first fraction: 1–3 s is considered to represent the moment of carbonation of the mortar. #Multiple graphite targets; *multiple GIS targets measured on the CO_2 from the same collected fraction; bulk = bulk fraction 45–63 μm.

Lab number	Sample code	Archaeological estimated age	Fraction	^{14}C age BP	±1σ	$F^{14}C$	±1σ	$\delta^{13}C$ (‰)	mg C
ETH-102876	17879-1	**775–785**	**1/1–3 sec**	**1367**	**22**	**0.844**	**0.002**	**–14.3**	**0.7**
			2*/4–6 sec	1507	22	0.829	0.002	–6.3	0.8
			2*/4–6 sec	1571	61	0.822	0.006	–11.5	<0.1
			2*/4–6 sec	1463	66	0.834	0.007	–12.0	<0.1
			3/7–9 sec	1413	30	0.839	0.003	–7.8	0.4
			5#/ rest of sample	2033	34	0.776	0.003	–11.6	0.2
			5#/ rest of sample	1987	22	0.781	0.002	–8.1	0.8
			6/bulk	1644	21	0.815	0.002	–12.4	0.8
ETH-102879	18741-1	**12th–13th c.**	**1/1–3 sec**	**771**	**33**	**0.908**	**0.004**	**–24.1**	**0.3**
			2/4–6 sec	900	22	0.894	0.002	–8.5	0.6
			3/7–9 sec	817	35	0.903	0.004	–14.8	0.3
			4/10–12 sec	831	63	0.902	0.007	–10.5	0.1
			5/ rest of sample	1237	22	0.857	0.002	–8.8	0.7
			6/bulk	1028	21	0.880	0.002	–7.7	0.4
ETH-102881	2211-1	**2nd half 12th c. - 1373**	**1*/1–3 sec**	**956**	**53**	**0.888**	**0.006**	**–27.5**	**0.1**
			1*/1–3 sec	**978**	**53**	**0.885**	**0.006**	**–26.6**	**<0.1**
			2/4–6 sec	1463	30	0.834	0.003	–21.7	0.4
			3/7–9 sec	1615	28	0.818	0.003	–15.5	0.5
			4/10–12 sec	1550	25	0.825	0.003	–15.2	0.4
			6/bulk	1840	23	0.795	0.002	–17.9	0.6
ETH-102883	16507	**Late 12th c.**	**1*/1–3 sec**	**993**	**153**	**0.884**	**0.017**	**–17.9**	**0.1**
			1*/1–3 sec	**901**	**156**	**0.894**	**0.017**	**–17.6**	**0.1**
			1*/1–3 sec	**1076**	**73**	**0.875**	**0.008**	**–9.9**	**0.1**
			2/4–6 sec	1189	39	0.862	0.004	–20.3	0.2
			3/7–9 sec	1135	22	0.868	0.002	–13.4	0.7
			4/10–12 sec	1238	33	0.857	0.004	–15.0	0.3
			5#/ rest of sample	1738	23	0.805	0.002	–9.4	0.7
			5#/ rest of sample	1726	23	0.807	0.002	–9.0	0.7
			6/bulk	1514	23	0.828	0.002	–13.9	0.6

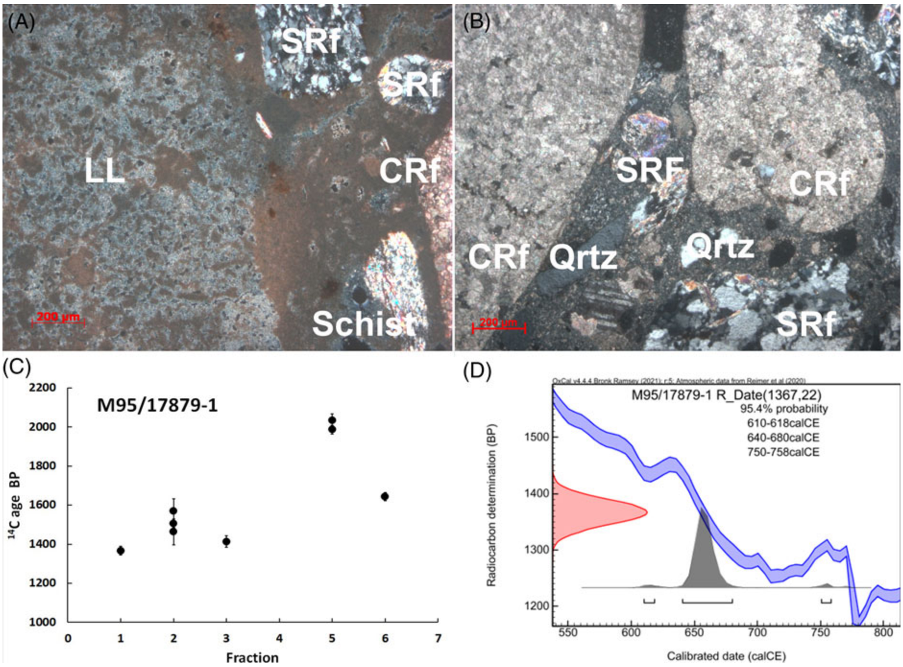

Figure 2 (A) photomicrograph of sample 17879, PPL. SRf=silicate rock fragments, LL=lime lump, CRf=carbonate rock fragment, Qrtz=quartz; (B) photomicrograph of sample 957, PPL; (C) Results of radiocarbon dating sample ETH-102876. Fraction 1/ 1–3 s is taken as a reliable radiocarbon age and calibrated age is shown in D. Fraction 5 (rest of sample dissolved after 12 s) is the significantly older as well as the bulk (Fraction 6).

Table 2 Calibrated (95.4% confidence level) radiocarbon ages. Samples marked with * were published in Caroselli et al. (2020).

ETH#	^{14}C age	±1 σ	Name	Unmodeled (BCE/CE) from	to
88631*	1180	32	R_Combine 6577ff, 45–63 µm	729	961
88628*	1304	26	R_Combine 957ff, 45–63 µm	660	769
102876	1367	22	R_Date M95/17879-1	610	758
102879	771	33	R_Date M95/18741-1	1219	1284
102881	967	38	R_Combine M79/2211-1	995	1165
102883	1037	61	R_Combine M94/16507	883	1161

presence of binder related particles indicates that the firing process was not efficient, not uniform, and that the binder selection and sieving operations were not carried out properly. In addition, most of the bedding mortars have aggregates with comparable characteristics: very coarse grain size (up to 2 cm) along with unselected medium and fine sand. Fragments of silicate metamorphic rocks prevail in the sand, while carbonates are few or absent (Figure 3A1, 3B1, and 3C1). Finally, dissolution and recrystallization of the binder are often observed (in some cases the phenomenon is extensive). All these common features make it possible to

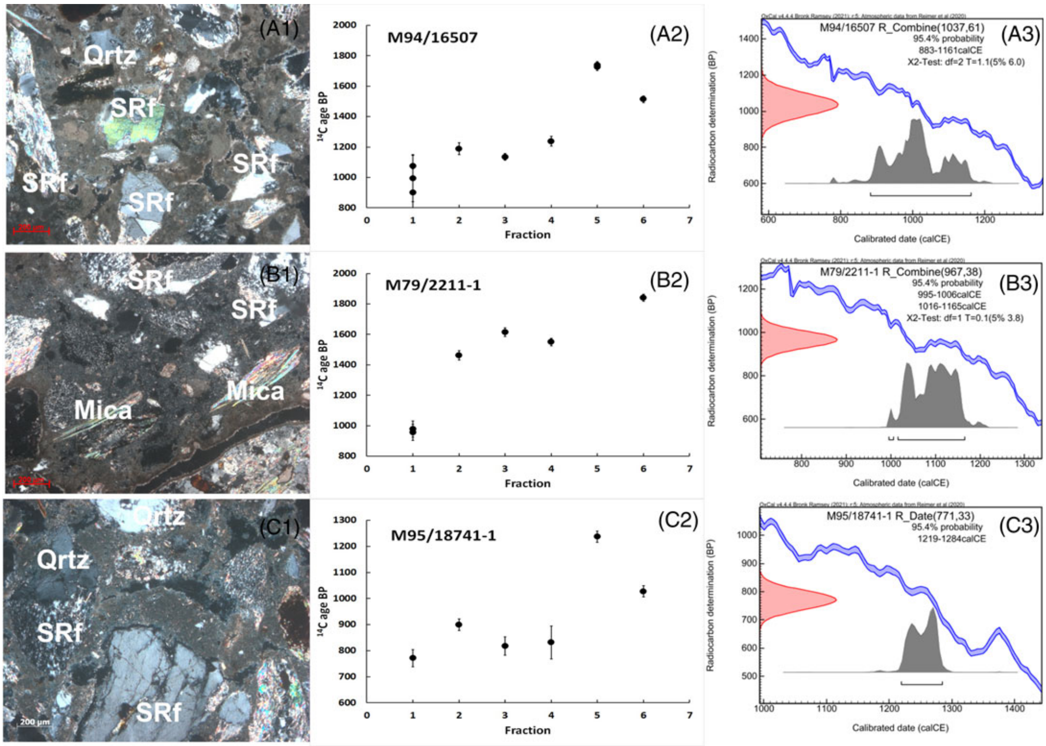

Figure 3 (A) sample 16507; A1- photomicrograph, PPL; A2-Results of radiocarbon dating sample ETH- 102883. Three analysis (gas ion source) were combined of Fraction 1/ 1–3 s, which is taken as a reliable radiocarbon age and calibrated age is shown in A3. Fraction 5 (rest of sample dissolved after 12 s) is the significantly older as well as the bulk (Fraction 6). (B) sample 2211; B1- photomicrograph, PPL; B2- Results of radiocarbon dating sample ETH-102881. Two analyses (gas ion source) were combined of Fraction 1/ 1–3 s, which is taken as a reliable radiocarbon age and calibrated age is shown in B3. Fraction6 (bulk) is the significantly older. (C) sample 18741; C1- photomicrograph, PPL; C2- Results of radiocarbon dating sample ETH- 102879. Fraction 1/ 1–3 s is taken as a reliable radiocarbon age and calibrated age is shown in C3. Fraction 5 (rest of sample dissolved after 12 s) is the significantly older as well as the bulk (Fraction 6). Legend in photomicrograph: SRf=silicate rock fragments, Qrtz=quartz.

identify a homogeneous group of mortars whose archaeological attribution appears consistent with petrographic observations.

Sample 16507 is a lime bedding mortar collected from the Egino tower. The radiocarbon dating resulted in 10,37BP (±61) (Table 1). The calibrated date is 883–1161 CalCE (Table 2 and Figure 3A2–3) in agreement with the archaeological hypotheses (late 12th century: Boschetti-Maradi 2005:64–65). Unfortunately, the calibration curve here meets a plateau and the range is somewhat large (Figure 4).

Sample 2211 comes from the Northern perimeter wall W116 (Figure 1) and it is quite interesting, because its dating was very uncertain within the late Romanesque period. The archaeological date was posed from second half 12th century to the year 1373 (Goll 2013: 42–43). Petrographically the mortar was inserted in the same group as the previous sample (Figure 3B1). The resulted combined date is 967 BP (±38) (Table 1), calibrated 995–1165 CalCE (Table 2 and Figure 3B2–3), on the lower range of archaeological expectations, but still consistent with sample 16507.

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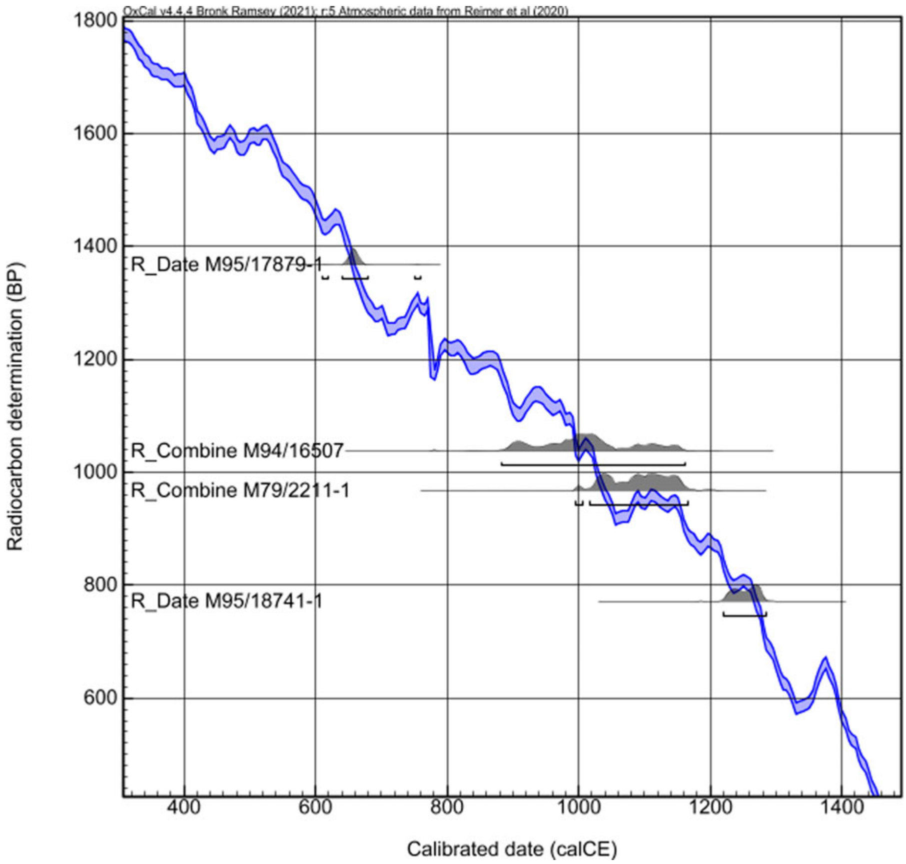

Figure 4 Sequence of obtained for mortar samples. The wide range of calibrated ages is partly due to lower precision of gas ion source analysis and partly due to the calibration curve.

Not much is known about the building from which sample 18741 was taken, either its function or other features. This sample, from a wall excavated immediately south of the church (Figure 1), also underwent binder recrystallization phenomena. It must belong to a period after the 10th century fire, but older than the 1500 tower. In addition, sample 18741 differs slightly from the previous group because the sand is completely free of carbonate aggregates and well sorted (Figure 3C1). The date obtained 771 BP (±33) (Table 1) yields a calibrated date 1219–1284 CalCE (Table 2 and Figure 3C2-3). Therefore, this sample can be attributed to a later phase than the previous two samples in a precise and narrow time interval.

DISCUSSION

Absolute radiocarbon dating of the mortars after sequential dissolution showed that the samples attributed to the Carolingian phase are clearly distinguishable from the Late Romanesque ones (Figure 4). While the dated sample of the church obtained a date consistent with the results of dendrochronology (Table 2; Caroselli et al. 2020), for the samples taken from the buildings of the courtyard of the Carolingian Monastery, for which no other absolute

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dating were available, the situation proved to be complex. Furthermore, the mortars of the presumed Carolingian phase II additions (light blue buildings in Figure 1) did not show homogeneous characteristics, such as to attribute them with certainty to a different phase.

The two dated samples from the monastery buildings both yielded older dates than assumed by archaeological studies. They showed similar petrographic characteristics: unsorted carbonate-rich sand and high amount of binder. The binder-enriched fine fraction of the previously published sample 957 had been prepared and dated twice giving slightly different results (1237 BP and 1234 BP ± 47 the first preparation; 1360 and 1384 ± 58 the second preparation) which combined led to a dating of 1304 ± 26 (Table 2; from Caroselli et al 2020). The results not in perfect agreement and older than the archaeological expectations, had suggested to discard them. However, the dating result of the other sample 17879, also from the monastery buildings, gave a date of 1367 BP (±22), which is consistent with the result of the second preparation of sample 957. This new result led us to reconsider the discarded previous result and suggests further dating of other samples from the same phase of the monastery. This ^{14}C date contradicts the archaeological evidence, which clearly demonstrates that the convent walls were built against the church, the completion of which is dated by dendrochronology to the year 775/6, a date also confirmed by the ^{14}C dating of mortar sample 6775 from the church, which is younger than the samples from the convent buildings.

Since the church sample, like the archaeological samples from the convent, was taken from the lower part of the walls, close to the foundations, this discrepancy cannot be explained by a longer construction time of the church. Therefore, the generally accepted construction sequence: church → convent → Holy Cross chapel might have to be abandoned. Instead, the ^{14}C dates seem to indicate that construction first started on the buildings of the convent, and that the church was added later, at a time when the convent walls had not yet reached the site of the church. Then, after the church was completed, the convent walls were extended to the church and connected to it. Should this be true, the dendrochronological date of the church, 775/6, might come close to the date of completion of the whole monastery. The archaeological record does allow for such a sequence, even though it is highly unusual. For this reason, until now this possibility was not contemplated. In the construction layers of the monastery, however, archaeologists have repeatedly documented what seemed to be remnants of previous buildings, such as fragments of painted plaster, fragments of mortar floors, and brick fragments. Since they were few in number, no interpretation was based on them. Given the new data, however, they might be interpreted as belonging to an earlier church, which was demolished and replaced by the present church towards the end of the construction period of the monastery. The presence of an earlier church might also explain why the Carolingian church was built towards the end of the construction period, as the older church could have been used by workmen and monks for worship before it was replaced by a larger church more fitting an important monastery.

The assumption of an earlier construction date for the monastery would have profound historical and archaeological implications. Even if a start of construction activities at the lower end of the ^{14}C range, around the mid-8th century is assumed, not too distant from the completion date of the church in 775/6, this would implicate a radically different political and historical context. The founding of the monastery has until now been connected by most scholars to the conquest of the Lombard kingdom by Charlemagne in 774 (e.g., Goll 2013; Sennhauser 2013; Hüglin and Cassitti 2020). After the conquest, Müstair and the Venosta valley were no longer situated on the border between the territories of two rival powers.

The construction of the monastery was therefore interpreted as a move to strengthen control of the region and of the transit routes to the southern parts of the Carolingian sphere of influence. The political situation before 774, on the other hand, was very different. The Venosta Valley formed a contested border region controlled intermittently by the Lombards and the Bavarians. In the middle of the 8th century, the Venosta valley was ruled by the Lombards, while the region north of the Resia pass was controlled by the Bavarians. In 746 Ratchis, the King of the Lombards, decreed the fortification of the borders of the kingdom and strict controls on movements across the border. The Müstair valley, with the Umbrail pass which provided direct access to the heart of the Lombard kingdom, would have been of great strategic importance in this setting. This might explain the construction of such a large monastic site on this spot. Irmtraut Heitmeier has proposed a similar hypothesis in 2013, which has not been widely received as there was no archaeological data to corroborate it. She suggested that construction of the monastery was initiated by the Lombard King Desiderius around 768, in order to contrast the expansion of the kingdom of the Franks (Heitmeier 2013:170–171). Since the political situation a decade earlier was similar, this explanation would be compatible with the new ^{14}C dates as well. These hypotheses however need to be corroborated by further significant number of samples and dating, and are thus still only a possibility.

For the Late Romanesque phase, the archaeological dating of the Egino tower (sample 16507) is in agreement with the ^{14}C dates. The similarity of mortars from the Egino tower and perimeter wall, and the correspondence between the ^{14}C dates indicates that they were probably erected at the same time. This allowed a more precise dating of the perimeter wall, and suggests that both the wall and the Egino tower were part of a major construction phase within the convent, which coincided with the time the monastery was turned into a female convent. The building of unknown origin and function positioned close to South annex (S-wall K715) should be attributed to this late Romanesque phase in a period between 1219–1284 CalCE. It is therefore younger than the Egino-tower and does not belong to the same construction phase, as previously assumed. Its relationship to other remnants of buildings to the west, which are also attributed to this period, should be examined through further sampling.

CONCLUSION

The technique of radiocarbon dating of mortars after sample preparation and treatment by the sequential dissolution method has been shown to be able to distinguish samples from buildings attributed to different phases. Moreover, as a result of this research, established theories have been challenged and new areas of discussion opened up. However, to corroborate these hypotheses it would be necessary to analyze and date a substantial number of samples in order to obtain conclusive results. When archaeologically certain data are not available, dating just two mortar samples cannot be considered sufficient to validate or disprove a new theory.

The interdisciplinary research method adopted can therefore be considered very effective because:

- archaeological research and petrographic results were complemented by radiocarbon dating of the mortars. Each discipline was able to provide some data that, taken alone, showed limitations and open questions. By integrating the data obtained from the different methods available, it was possible to advance our knowledge of the construction of the Müstair monastery.

- New hypotheses were opened, contributing scientific data to the archaeological debate on the various possible interpretations of material culture. Were the Carolingian building sites of the church and monastery carried out by two different teams? Were the builders of the church purposely called upon to design and construct such an important building and decorate it according to state-of-the-art standards?

The complexity of historical research of the past is characterized by controversies that are fundamental to the advancement of knowledge. In this paper, some attributions have been discussed and some confirmed, while others still need further investigation.

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