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Interactive comment on "Lowlands fluvial sedimentation enlightens glacial dynamics in narrow valleys during the Last Glacial Maximum (Venetian Forealps, Italy)" *by* Sandro Rossato et al.

S. Winkler (Referee)

stefan.winkler@uni-wuerzburg.de

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General comments:

The discussion article addresses an interesting and important topic. Whereas the focus of research on glacial dynamics and chronology during the LGM in the European Alps naturally has focused on the well-developed moraine sequences major valley glaciers formed when they flowed from their inner Alpine valley sections out onto the foreland, the investigated former Brenta glacier system is of a different type. Confined to a narrow valley it lacks any comparable assemblage of landforms and sediment that would allow easy reconstruction of its outline and chronology, and thus also of its glacial

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Discussion paper

dynamics. The authors tackle the challenge by applying a multi-proxy approach using different (mainly sedimentological) methods. They, furthermore, aim to link the lithostratigraphical record of the Brenta megafan with the morphological and sedimentological record preserved in the valley. Given the lack of chronological record within the valley itself due to apparent lack of suitable sites and problems of applying surface exposure dating on glacial landforms and bedrock, this seem an appropriate attempt.

The strength of the article is, surely, that a number of different sedimentological methods are combined and that very detailed field work has been carried out to describe and carefully interpret the investigated key sites. The related sedimentological analysis is very sound and altogether the reader can easily follow the argumentation thanks to a number of well-prepared illustrations. The latter is not trivial due to the fact that especially if a study is based on such key sites the reader unfamiliar with those often finds it difficult to assess the detailed interpretation presented in similar stories. This is not the case here.

Finally, the authors develop and discuss some hypothesis about the glacial dynamics of the former Brenta glacier based on their chronological, sedimentological, and chronological findings. Although their conclusions are valid, I have the feeling that alternative explanations could also well be brought forward as reasons to match the evidence presented. In my specific comments below I will address those and want to invite the authors to consider at least mentioning them in the discussion section. Those are hypothesis as well and I, by all means, do not insist that the authors need to change their original interpretation. But by briefly discussing those alternatives (and potentially rejecting them based on their field experience and findings) the authors would show that their explored a wider range of possible explanations. This would further improve the already well presented and written manuscript.

Specific comments:

The authors summarise their conclusions regarding the glacial dynamics within the nar-

row valley as following. “Glaciers flowing across narrow gorges turned out to be possibly slowed/blocked by such morphology and, if a lateral valley exists, glacial/sediment fluxes can be diverted. Moreover, narrow valleys may induce glaciers to bulge and form icefalls at their front, preventing the formation of terminal moraines”.

I have to admit that I am not familiar with the study region and base my comments on my experience in different regions and with modern mountain glaciers. For me, it is not at all surprising that terminal moraines are not present in such relatively narrow mountain valleys. I see, however, not the necessity to infer specific processes like bulging or a specific morphology of the glacier front (like ice falls). Firstly, a plausible explanation for the lack of terminal moraines in the valley is their easy potential erosion. Unlike in the case of LGM valley glacier flowing onto the wide, open forelands a terminal moraine once built is hard to preserve in a setting of a narrow valley where postdepositional glaciofluvial erosion may immediately start eroding the moraine during the initial retreat from the terminal position. Subsequent fluvial erosion (confined to the narrow valley floor) and other geomorphological processes (slope processes etc.) may also contribute to the difficult preservation of terminal moraines and other glacial landforms. By contrast, preservation potential of the major lobate-shaped moraine sequences in the foreland seems much easier as only where Late Glacial or postglacial (glacio)fluvial actions concentrates moraines are easily eroded.

Another explanation for the lack of terminal moraines can be deduced from the different processes of moraine formation. Lateral moraines in high mountain ranges (modern as well as LGM ones) are predominately formed by dumping of supraglacial debris. This well-established mechanism seems undisputed and the less compacted and consolidated character of their glacial diamicts demonstrates this very nicely (as also pointed out by the authors in their description and interpretations of lateral moraine in their study area). With terminal moraine formation there are, however, multiple individual processes involved, partly in complex interaction (ranging from simple pushing to glaciotectonic thrusting). At most modern mountain glacier where terminal moraine has

been studied during the (few) occasions their advanced in more recent decades dumping of debris was either absent or an insignificant contribution to moraine formation. By contrast, most processes that have been identified depend or are at least substantially influenced by the properties of the glacier bed material at the glacier margins, in particular its shear strength and deformability. This applies to situations with unfrozen bed conditions at the glacier margin (pushing) as well as with permafrost at the former glacier margins (glaciotectonic processes). As a result, even with an advancing glacier front no or only a small terminal moraine may be formed if it rest on bedrock or a thin layer of sediment (especially if it has a high shear resistance). Based on these considerations regarding potential moraine formation processes I don't see the necessity to induce any form of "bulging" or a particular morphology of the ice front to explain a lack of terminal moraines. By contrast, I am aware of a modern analogues where a small mountain glacier advanced too fast (but did not surge) to develop a terminal moraine during the ongoing advance where it showed a steep, ice cliff-shaped glacier front. At the time the advances culminated and slowed down, a terminal moraine was pushed up in usual fashion. Summarising, a valid hypothesis for the lack of terminal moraines in the narrow sections of the valley could simply be the different framework (topography, glacier bed material etc.) during culmination of the LGM advance preventing a glacier confined to a narrow valley (possibly with some exposed bedrock at its glacier bed and the lack of deformable soft sediment) to effectively build up a terminal moraine. This hypothesis should be discussed in the related section of the manuscript – and I am more than happy that the authors present evidence that it can be rejected. But currently some readers may ask way the authors did not consider this apparent "easy" and "obvious" solution.

The other explanation offered by the authors that I suggest could be discussed in the light of an alternative explanation is the hypothesis of narrow gorges slowing down/blocking glacier flow and cause diversion. In this context the altitudinal difference between the lateral moraines and the valley floor is additionally mentioned as indication of a blocking action (or bulging) of the glacier flowing through the narrow valley.

Although I can follow the argument given by the authors, it is contradictory to common view that narrow valley channelise ice flow and cause higher flow rates (and increase erosional glacial power). According to some hypothesis promoted by researchers with a background in engineering ice flow mechanics should be seen as comparable with flow mechanics of water. Consequently a certain ice volume transferred from its accumulation area in inner Alpine catchments towards the glacier front as determined by the glacier's mass budget should theoretically speed up if the valley in its flow paths narrows (and not slow down). Any "overspill" and diversion could easily explained by the capacity of the narrow valley not sufficient even with an increased ice flow to transfer the entire ice mass. The huge difference between lateral moraines and valley bottom may indicate that the valley was at the maximum of its capacity with a huge ice mass occupying the valley. In this context, I am also not aware that supraglacial debris (even if potentially integrated into the en- or subglacial debris transport pathways through extensive crevassing) considerably slows down ice flow in those regions currently be the home of extensively debris-covered glaciers. If theoretically a narrow valley inhibits efficient ice flow and obstructs normal mass transfer it would even be a possible cause of glacier surges (that despite multiple theories for their causes all have in common that the normal mass transfer is inhibited until a certain threshold is reached for the surge to start).

I am confident that by exploring the hypothesis mentioned above in the discussion chapter the part of the discussion paper referring to glacial dynamics could be strengthened by providing some alternative views for the author's interpretations of their great field and sedimentological evidence. I am far from insisting that they need to change their conclusions, but feel that currently there is a lack of addressing some common views in the discussion section and some readers may interpret it as some obvious explanations having been overlooked.

Technical corrections:

The manuscript is mostly well structured and written. A few editorial changes may be

addressed during the revision. I only point out some few points here.

1.) I feel that the title is a bit strong by using the phrase “enlightens glacial dynamics”. Even without considering my comments above, there are still some uncertainties that remain. Perhaps the authors could find an alternative title.

2.) In a few sentences, like page 2 line 13 ff., there is an excessive use of commas. Not all are necessary and I would recommend that during the final check of the manuscript, some may be removed.

3.) The type of radiocarbon-dated material and its position are given in the related table. I only miss information about the sampled thickness (I assume 1 cm?).

4.) Wasn’t it possible to asses a potential difference between lodgement and melt-out till and make a judgement here?

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