Recognition and Occurrence of Different Sediment-Water Flows Triggered by High-Magnitude Hydrological Events in Mountain Catchments

Andrea Brenna\textsuperscript{1}, Nicola Surian\textsuperscript{1}, Marco Borga\textsuperscript{2}, Massimiliano Ghinassi\textsuperscript{1}, and Lorenzo Marchi\textsuperscript{3}

\textsuperscript{1}Department of Geosciences, University of Padova, Padova, Italy (andrea.brenna@unipd.it)
\textsuperscript{2}Department of Land, Environment, Agriculture and Forestry, University of Padova, Padova, Italy (marco.borga@unipd.it)
\textsuperscript{3}Research Institute for Geo-hydrological Protection, National Research Council (CNR IRPI), Padova, Italy (lorenzo.marchi@cnr.it)

Sediment mobilization in small-medium size mountain catchments occurs by different flow types, categorized as debris-flows, hyperconcentrated-flows and water-flows, depending on the physical mechanisms governing flow rheology and particles interaction. During high-magnitude flow events, such transport mechanisms may take place concurrently in the same catchment at different sites of the channel network. One of the most important tasks in investigating dynamics of floods in these mountain catchments is to identify the transport mechanisms, since different flow types induce peculiar geomorphological hazards and dynamics. This work aims to improve criteria to recognize different flow types, with particular regard to hyperconcentrated-flows, and to analyze the transport mechanisms in mountain catchments in response to high-magnitude hydrological events.

Since direct monitoring of sediment mobilization during a flood is extremely difficult, a sound alternative is to consider the characteristics of the deposited material, which depend on the rheological proprieties of related flow. Through an extensive literature review, we identified the diagnostic criteria of the different flow types, grouping them in morphological and sedimentological evidences. A field-survey worksheet has been developed to ease the field-data collection and interpretation. The case-study selected for applying the survey procedure is the Tegnas catchment (Dolomites, Italy), a mountain basin draining an area of 51 km\textsuperscript{2} affected by the Vaia Storm in October 2018, which induced large floods in several catchments of the Eastern Italian Alps. The deposits field-survey has been conducted in 35 sub-reaches of the Tegnas river and its major tributaries. In addition, we carried out detailed grain-size analyses, measured the angle of clasts-imbrication and collected samples for estimating the vegetal organic matter content through Loss-of-ignition procedure.

Field criteria allowed us to classify each sub-reach according to the deposits left after the event. Most of the steep tributaries have been interested by debris-flows, but also hyperconcentrated-flows have been recognized. Along the main stem, water-flow was the dominant process, although debris-flows and hyperconcentrated-flows deposits are documented where channel slope was
very high (i.e. from 9 to 21%). Hyperconcentrated-flow deposits occur also in the lower sub-reaches (i.e. channel slope from 0.3 to 6%), either at the confluence with debris-flow fed tributaries of where severe bank erosion occurred. We statistically analyzed data about clast imbrication angle (δ) and content of vegetal organic matter (OM_{LOI}) obtaining significant results for both parameters. δ measured in debris-flow (50°-65°) and hyperconcentrated-flow deposits (45°-60°) is considerably higher than in water-flow sediments (30°-40°). Debris-flow and hyperconcentrated-flow deposits have higher OM_{LOI} (2.5-5.5%) than water-flow deposits (1.5-3%).

The combination of field diagnostic-criteria and quantitative measure of additional parameters allows a reliable recognition of the flow types based on post-flood survey. Besides, this study allowed to point out that during high-magnitude floods the sediment mobilization in small-medium size catchments occurs through mechanisms that can be different from those expected for ordinary hydrological events using morphometric approaches. Solid material concentration or dilution (e.g. due to lacking of sediment sources or sediment disconnectivity) can explain the “unexpected” flow types during high magnitude events.