Mafic replenishments into floored silicic magma chambers

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ABSTRACT

Commingling between contemporaneous mafic and felsic magmas is now widely recognized in a broad range of intrusions and intrusive complexes. These interactions are important features for two main reasons: (1) the rapidly chilled margins of mafic magma against silicic magma commonly preserve the compositions of mafic liquids, and (2) because the mafic magma solidifies rapidly, the resulting (final) configurations of mafic and felsic magmas can provide insights into physical processes and changing viscosity contrasts and rheologies of magmas and felsic crystal mush during crystallization of the mafic magma.

Mingling of contrasted magmas was first recognized in the 1950s. Wider recognition of interactions between mafic and silicic liquids led to concepts of “net-veining” in the 1960s, “intramagmatic flows” (chilled basaltic layers separated by felsic cumulates) in the 1970s, and in the 1990s to “mafic-silicic layered intrusions” (MASLI), which could be as much as a few kilometers thick and more than 100 km² in area. It was quickly appreciated that these MASLI preserved stratigraphic records of mafic replenishments into silicic magma chambers floored by felsic crystal mush. Volcanic studies had anticipated the occurrence of this last type of intrusion on the grounds that extensive ponding of basaltic magmas beneath silicic chambers was seen to be essential to keep large silicic systems like Yellowstone active for millions of years. This paper looks at the history of changing perceptions and interpretations of magma mingling and whether or not “sill complexes” are distinct from mafic-silicic layered intrusions. The stratigraphy of mafic-silicic layered intrusions records changing magmatic compositions, events, and processes in a temporal framework comparable to that provided by coeval volcanic rocks. As a result, careful study of MASLI has great potential for linking plutonic and volcanic processes and events.

Keywords: Magma mingling, granite, gabbro, net-veining, mafic-silicic layered intrusions

INTRODUCTION

Mafic and silicic plutonic associations have long fascinated field geologists and their students—probably because of the striking character of different geometric arrangements of the highly contrasted rock types and because of the implications for separate magmatic reservoirs at depth that brought the contrasted magmas together. Wilcox (1999) surveyed the history of ideas about mixing magmas from the 1850s to the 1970s in both volcanic and plutonic associations. Many early reports described rounded fine-grained mafic rock in association with granite, and some of these suggested that gabbro and granite were emplaced at nearly the same time (Lossen 1882; Erdmannsdorffer 1908—in Wilcox 1999). Composite dikes with basaltic margins and a silicic interior were widely described and particularly common in the British Tertiary, but all were interpreted as later injections of rhyolite after the basalt had solidified (e.g., Judd 1893). Although hybrid-looking rocks commonly occurred in other gabbro-granite associations, none were unambiguously interpreted as liquid-liquid interactions. Nonetheless, liquid-liquid interactions were considered a possible interpretation of hybridization (Harker 1904; Bailey and Thomas 1930). Reaction and metasomatism were other common explanations on into the 1960s (e.g., Compton 1955; Chapman 1962) for features that we would now recognize as mingling and hybridization between coexisting magmas. Surprisingly, it was not until the 1950s that a study unequivocally interpreted basalt-granite contacts to have formed initially between two liquids (Wager and Bailey 1953). Their observations led to several studies that similarly recognized liquid-liquid contacts (Bailey and McCallien 1956; Elwell et al. 1962; Blake et al. 1965) between gabbro and granite. Initially, nearly all studies suggested that silicic magma invaded gabbro, probably because the gabbro was the more abundant lithology and because silicic melt remaining after the basalt had solidified commonly intruded fractures in basalt. The name applied to many of these occurrences, “net-veining,” emphasized that interpretation (e.g., Windley 1965). We now know that “net-vein complexes” where silicic “veins” separate closely packed chilled, pillow-like bodies of gabbro, either in dikes or in larger plutons, formed by flow of basaltic magma into granitic magma (Snyder et al. 1997); these now might more properly be termed basaltic pillow mounds that formed within silicic magma instead of water (Wiebe et al. 2001). The term “net-veining” should probably be restricted only to occurrences where granitic veins intrude solid gabbro and liquid-liquid contacts are absent.

Since the 1960s, interactions between mafic and silicic magmas have been widely recognized around the world both in extensional and arc terranes of all ages (Table 1). These occurrences have provided many new insights into plutonic plumbing systems that potentially link with volcanic activity at the Earth’s surface. Some