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(54) **Titre : TRAITEMENT DU CANCER FAISANT APPEL A DES ASSOCIATIONS D'INHIBITEURS DE L'ERK ET DE LA RAF**
(54) **Title: CANCER TREATMENT USING COMBINATIONS OF ERK AND RAF INHIBITORS**

(57) **Abrégé/Abstract:**
The present invention provides, inter alia, methods of treating or ameliorating the effects of a cancer in a subject. The methods include administering to the subject an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a type 1 RAF inhibitor (such as dabrafenib) or another RAF inhibitor (such as regorafenib) or a pharmaceutically acceptable salt thereof, to treat or ameliorate the effects of the cancer. Also provided are pharmaceutical compositions and kits for treating or ameliorating the effects of a cancer in a subject.

ABSTRACT

The present invention provides, *inter alia*, methods of treating or ameliorating the effects of a cancer in a subject. The methods include administering to the subject an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a type 1 RAF inhibitor (such as dabrafenib) or another RAF inhibitor (such as regorafenib) or a pharmaceutically acceptable salt thereof, to treat or ameliorate the effects of the cancer. Also provided are pharmaceutical compositions and kits for treating or ameliorating the effects of a cancer in a subject.

Date reçue/Date received 2024-05-31

CANCER TREATMENT USING COMBINATIONS OF ERK AND RAF INHIBITORS

[0001] Intentionally left blank.

FIELD OF INVENTION

[0002] The present invention provides, *inter alia,* methods, kits, and pharmaceutical compositions for treating or ameliorating the effects of a cancer in a subject using (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a type 1 RAF inhibitor, such as dabrafenib or a pharmaceutically acceptable salt thereof, to treat or ameliorate the effects of the cancer.

[0003] Intentionally left blank.

BACKGROUND OF THE INVENTION

[0004] Drug inhibitors that target components of the mitogen-activated protein kinases (MAPK) signaling pathway show clinical efficacy in a variety of cancers, particularly those bearing mutations in the BRAF protein kinase. Both RAF

Date reçue/Date received 2024-05-31

and MEK kinase inhibitors are approved for single-agent use in advanced metastatic BRAF mutant melanoma, and the combination of dabrafenib and trametinib is currently undergoing Food and Drug Administration (FDA) review for this indication. Either alone or in combination, BRAF and MEK inhibitors show variable activity in other cancers, with promising efficacy in BRAF mutant thyroid and lung cancer, as well as possible marginal activity in BRAF mutant colorectal cancer.

[0005] Varying patterns of clinical efficacy are seen with BRAF and MEK inhibitors. Both the extent and penetrance of initial tumor regression, as well as duration of response before disease progression, varies uniquely according to each drug class when given alone, or when administered in either sequential or concurrent combination strategies. To date, concurrent dabrafenib and trametinib combination therapy appears to be the preferred intervention for BRAF mutant melanoma.

[0006] As with other targeted therapies, patterns of disease response to RAF and MEK inhibitors appear to be influenced by the intrinsic genetic heterogeneity present in the cancers where the drugs are used. For instance, it has been shown that certain genetic alterations, including PTEN and other changes that activate the PI3K cell growth signals, may predict a poor initial response, and/or relatively rapid progression, in BRAF mutant melanoma treated with the RAF inhibitor vemurafenib. Likewise, direct mutations in MEK gene loci appear to emerge in tumors that have progressed following either BRAF, MEK or combined drug treatment. Several additional examples, from RAS and RAF gene amplification and splicing mutations, suggest that acquired drug resistance is produced when oncogenic pleiotropy encounters the selective pressure of targeted drug treatment.

[0007] Therefore, novel targeted agents would ideally inhibit diverse nodes of oncogenic pathways, and also be effective in combinations by inducing a

Date reçue/Date received 2024-05-31

burden of selective pressure that exceeds the adaptive capacity of diverse cancer genomes. The present application is directed to meeting, *inter alia*, the need for novel targeted agents.

SUMMARY OF THE INVENTION

[0008] One embodiment of the present invention is a method of treating or ameliorating the effects of a cancer in a subject in need thereof. This method comprises administering to the subject an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a type 1 RAF inhibitor or a pharmaceutically acceptable salt thereof, to treat or ameliorate the effects of the cancer.

[0009] Another embodiment of the present invention is a method of treating or ameliorating the effects of a cancer in a subject in need thereof. This method comprises administering to the subject an effective amount of (i) BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is dabrafenib or a pharmaceutically acceptable salt thereof, to treat or ameliorate the effects of the cancer.

[0010] An additional embodiment of the present invention is a method of effecting cancer cell death. This method comprises contacting the cancer cell with an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a type 1 RAF inhibitor or a pharmaceutically acceptable salt thereof.

[0011] A further embodiment of the present invention is a kit for treating or ameliorating the effects of a cancer in a subject in need thereof. This kit comprises an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which

Date reçue/Date received 2024-05-31

is a type 1 RAF inhibitor or a pharmaceutically acceptable salt thereof, packaged together with instructions for their use.

[0012] An additional embodiment of the present invention is a pharmaceutical composition for treating or ameliorating the effects of a cancer in a subject in need thereof. This pharmaceutical composition comprises a pharmaceutically acceptable diluent or carrier and an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a type 1 RAF inhibitor or a pharmaceutically acceptable salt thereof, wherein administration of the first and second anti-cancer agents provides a synergistic effect compared to administration of either anti-cancer agent alone.

[0013] Another embodiment of the present invention is a method of treating or ameliorating the effects of a cancer in a subject in need thereof. This method comprises administering to the subject an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a RAF inhibitor selected from the group consisting of AAL881 (Novartis); AB-024 (Ambit Biosciences), ARQ-736 (ArQule), ARQ-761 (ArQule), AZ628 (Axon Medchem BV), BeiGene-283 (BeiGene), BIIB-024 (MLN 2480) (Sunesis & Takeda), b-raf inhibitor (Sareum), BRAF kinase inhibitor (Selexagen Therapeutics), BRAF siRNA 313 (tacaccagcaagctagatgca) and 253 (cctatcgttagagtcttcctg) (Liu *et al.*, 2007), CTT239065 (Institute of Cancer Research), DP-4978 (Deciphera Pharmaceuticals), HM-95573 (Hanmi), GW-5074 (Sigma Aldrich), ISIS 5132 (Novartis), LErafAON (NeoPharm, Inc.), LBT613 (Novartis), LGX-818 (Novartis), pazopanib (GlaxoSmithKline), PLX5568 (Plexxikon), RAF-265 (Novartis), RAF-365 (Novartis), regorafenib (Bayer Healthcare Pharmaceuticals, Inc.), RO 5126766 (Hoffmann-La Roche), TAK 632 (Takeda), TL-241 (Teligene), XL-

Date reçue/Date received 2024-05-31

281 (Exelixis), pharmaceutically acceptable salts thereof, and combinations thereof, to treat or ameliorate the effects of the cancer.

[0014] An additional embodiment of the present invention is a method of effecting cancer cell death. This method comprises contacting the cancer cell with an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a RAF inhibitor selected from the group consisting of AAL881 (Novartis); AB-024 (Ambit Biosciences), ARQ-736 (ArQule), ARQ-761 (ArQule), AZ628 (Axon Medchem BV), BeiGene-283 (BeiGene), BIIB-024 (MLN 2480) (Sunesis & Takeda), b-raf inhibitor (Sareum), BRAF kinase inhibitor (Selexagen Therapeutics), BRAF siRNA 313 (tacaccagcaagctagatgca) and 253 (cctatcgttagagtcttcctg), CTT239065 (Institute of Cancer Research), DP-4978 (Deciphera Pharmaceuticals), HM-95573 (Hanmi), GW-5074 (Sigma Aldrich), ISIS 5132 (Novartis), LErafAON (NeoPharm, Inc.), LBT613 (Novartis), LGX-818 (Novartis), pazopanib (GlaxoSmithKline), PLX5568 (Plexxikon), RAF-265 (Novartis), RAF-365 (Novartis), regorafenib (Bayer Healthcare Pharmaceuticals, Inc.), RO 5126766 (Hoffmann-La Roche), TAK 632 (Takeda), TL-241 (Teligene), XL-281 (Exelixis), pharmaceutically acceptable salts thereof, and combinations thereof.

[0015] A further embodiment of the present invention is a kit for treating or ameliorating the effects of a cancer in a subject in need thereof. This kit comprises an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a RAF inhibitor selected from the group consisting of AAL881 (Novartis); AB-024 (Ambit Biosciences), ARQ-736 (ArQule), ARQ-761 (ArQule), AZ628 (Axon Medchem BV), BeiGene-283 (BeiGene), BIIB-024 (MLN 2480) (Sunesis & Takeda),

Date reçue/Date received 2024-05-31

b-raf inhibitor (Sareum), BRAF kinase inhibitor (Selexagen Therapeutics), BRAF siRNA 313 (tacaccagcaagctagatgca) and 253 (cctatcgttagagtcttcctg), CTT239065 (Institute of Cancer Research), DP-4978 (Deciphera Pharmaceuticals), HM-95573 (Hanmi), GW-5074 (Sigma Aldrich), ISIS 5132 (Novartis), LErafAON (NeoPharm, Inc.), LBT613 (Novartis), LGX-818 (Novartis), pazopanib (GlaxoSmithKline), PLX5568 (Plexxikon), RAF-265 (Novartis), RAF-365 (Novartis), regorafenib (Bayer Healthcare Pharmaceuticals, Inc.), RO 5126766 (Hoffmann-La Roche), TAK 632 (Takeda), TL-241 (Teligene), XL-281 (Exelixis), pharmaceutically acceptable salts thereof, and combinations thereof, packaged together with instructions for their use.

[0016] Another embodiment of the present invention is a pharmaceutical composition for treating or ameliorating the effects of a cancer in a subject in need thereof. This pharmaceutical composition comprises a pharmaceutically acceptable diluent or carrier and an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a RAF inhibitor selected from the group consisting of AAL881 (Novartis); AB-024 (Ambit Biosciences), ARQ-736 (ArQule), ARQ-761 (ArQule), AZ628 (Axon Medchem BV), BeiGene-283 (BeiGene), BIIB-024 (MLN 2480) (Sunesis & Takeda), b-raf inhibitor (Sareum), BRAF kinase inhibitor (Selexagen Therapeutics), BRAF siRNA 313 (tacaccagcaagctagatgca) and 253 (cctatcgttagagtcttcctg), CTT239065 (Institute of Cancer Research), DP-4978 (Deciphera Pharmaceuticals), HM-95573 (Hanmi), GW-5074 (Sigma Aldrich), ISIS 5132 (Novartis), LErafAON (NeoPharm, Inc.), LBT613 (Novartis), LGX-818 (Novartis), pazopanib (GlaxoSmithKline), PLX5568 (Plexxikon), RAF-265 (Novartis), RAF-365 (Novartis), regorafenib (Bayer Healthcare Pharmaceuticals, Inc.), RO 5126766 (Hoffmann-La Roche), TAK 632 (Takeda), TL-241 (Teligene), XL-281

Date reçue/Date received 2024-05-31

(Exelixis), pharmaceutically acceptable salts thereof, and combinations thereof, wherein administration of the first and second anti-cancer agents provides a synergistic effect compared to administration of either anti-cancer agent alone.

BRIEF DESCRIPTION OF THE DRAWINGS

[0017] The patent or application file contains at least one drawing executed in color. Copies of this patent or patent application publication with color drawing(s) will be provided by the Office upon request and payment of the necessary fee.

[0018] FIGS. 1A-C show the progress of a dose escalation study in a human malignant melanoma cell line (A375 cells) for month 1. Various treatments (trametinib (a type 2 MEK inhibitor), dabrafenib (a BRAF inhibitor), and BVD-523 (an ERK1/2 inhibior)) are as labeled.

[0019] FIGS. 2A-H show the results of a proliferation assay that tracks changes in sensitivity to the escalated agent(s) at month 1. Various treatments (trametinib, dabrafenib, BVD-523, and pacitaxel) are as labeled on the top of the graph. The caption to the right of the graph shows the various types of cells generated from the dose escalation study. For example, “dabrafenib” refers to the cells that have been treated with the highest dose of dabrafenib from month 1 of the dose escalation study. Parental refers to the control cells that have not been treated with drugs. FIGS. 2A-2C and 2G are normalized to control, whereas FIGS. 2D-2F and 2H show the raw data.

[0020] FIGS. 3A-3D show the progress of a dose escalation study in A375 cells for month 2. Various treatments (trametinib, dabrafenib, and BVD-523) are as labeled.

[0021] FIGS. 4A-H show the results of a proliferation assay that tracks changes in sensitivity to the escalated agent(s) at month 2. Various treatments

Date reçue/Date received 2024-05-31

(trametinib, dabrafenib, BVD-523, and pacitaxel) are as labeled on the top of the graph. The caption to the right of the graph shows the various types of cells generated from the dose escalation study. For example, "dabrafenib" refers to the cells that have been treated with the highest dose of dabrafenib from month 2 of the dose escalation study. Parental refers to the control cells that have not been treated with drugs. FIGS. 4A-4C and 4G are normalized to control, whereas FIGS. 4D-4F and 4H show the raw data.

[0022] FIGS. 5A-H show only the parental and BVD-523 cell line data from FIG. 4. Various treatments (trametinib, dabrafenib, BVD-523, and pacitaxel) are as labeled. FIGS. 5A-5C and 5G are normalized to control, whereas FIGS. 5D-5F and 5H show the raw data.

[0023] FIGS. 6A-D show the progress of the dose escalation study in a human malignant cell line (A375 cells) for month 3. Various treatments (trametinib, dabrafenib, and BVD-523) are as labeled.

[0024] FIG. 7 is a histogram showing the results of a proliferation assay as applied to cells grown in the DMSO control wells from the dose escalation assay.

[0025] FIGS. 8A-D are a set of line graphs showing proliferation assays for month 3 of the study. Various treatments (trametinib, dabrafenib, BVD-523, and pacitaxel) are as labeled on the top of the graph. The caption to the right of the graph shows the various types of cells generated from the dose escalation study. For example, "dabrafenib" refers to the cells that have been treated with the highest dose of dabrafenib from month 3 of the dose escalation study. Parental refers to the control cells that have not been treated with drugs.

[0026] FIGS. 9A-D show only the parental, dabrafenib, and BVD-523 cell line data from FIG. 8.

Date reçue/Date received 2024-05-31

[0027] FIG. 10A is a dose matrix showing % inhibition of the trametinib/dabrafenib combination in A375 cells using the Alamar Blue cell viability assay. FIG. 10B is a dose matrix showing excess over Bliss for the trametinib/dabrafenib combination. FIGS. 10C and 10D show % viability relative to DMSO only treated controls for dabrafenib and trametinib single agent treatments in A375 cells using the Alamar Blue cell viability assay. FIG. 10E shows % viability relative to DMSO only treated controls for dabrafenib and trametinib combination treatments in A375 cells using the Alamar Blue cell viability assay.

[0028] FIG. 11A is a dose matrix showing % inhibition of the trametinib/dabrafenib combination in A375 cells using the CellTiter-Glo cell viability assay. FIG. 11B is a dose matrix showing excess over Bliss for the trametinib/dabrafenib combination. FIGS. 11C and 11D show % viability relative to DMSO only treated controls for dabrafenib and trametinib single agent treatments in A375 cells using the CellTiter-Glo cell viability assay. FIG. 11E shows % viability relative to DMSO only treated controls for dabrafenib and trametinib combination treatments in A375 cells using the CellTiter-Glo cell viability assay.

[0029] FIG. 12A is a dose matrix showing % inhibition of the BVD-523/dabrafenib combination in A375 cells using the Alamar Blue cell viability assay. FIG. 12B is a dose matrix showing excess over Bliss for the BVD-523/dabrafenib combination. FIGS. 12C and 12D show % viability relative to DMSO only treated controls for dabrafenib and BVD-523 single agent treatments in A375 cells using the Alamar Blue cell viability assay. FIG. 12E shows % viability relative to DMSO only treated controls for dabrafenib and BVD-523 combination treatments in A375 cells using the Alamar Blue cell viability assay.

Date reçue/Date received 2024-05-31

[0030] FIG. 13A is a dose matrix showing % inhibition of the BVD-523/dabrafenib combination in A375 cells using the CellTiter-Glo cell viability assay. FIG. 13B is a dose matrix showing excess over Bliss for the BVD-523/dabrafenib combination. FIGS. 13C and 13D show % viability relative to DMSO only treated controls for dabrafenib and BVD-523 single agent treatments in A375 cells using the CellTiter-Glo cell viability assay. FIG. 13E shows % viability relative to DMSO only treated controls for dabrafenib and BVD-523 combination treatments in A375 cells using the CellTiter-Glo cell viability assay.

[0031] FIG. 14A is a dose matrix showing % inhibition of the trametinib/BVD-523 combination in A375 cells using the Alamar Blue cell viability assay. FIG. 14B is a dose matrix showing excess over Bliss for the trametinib/BVD-523 combination. FIGS. 14C and 14D show % viability relative to DMSO only treated controls for BVD-523 and trametinib single agent treatments in A375 cells using the Alamar Blue cell viability assay. FIG. 14E shows % viability relative to DMSO only treated controls for BVD-523 and trametinib combination treatments in A375 cells using the Alamar Blue cell viability assay.

[0032] FIG. 15A is a dose matrix showing % inhibition of the trametinib/BVD-523 combination in A375 cells using the CellTiter-Glo cell viability assay. FIG. 15B is a dose matrix showing excess over Bliss for the trametinib/BVD-523 combination. FIGS. 15C and 15D show % viability relative to DMSO only treated controls for BVD-523 and trametinib single agent treatments in A375 cells using the CellTiter-Glo cell viability assay. FIG. 15E shows % viability relative to DMSO only treated controls for BVD-523 and trametinib combination treatments in A375 cells using the CellTiter-Glo cell viability assay.

Date reçue/Date received 2024-05-31

[0033] FIGS. 16A-D are a set of images showing Western blot analysis of MAPK signaling in A375 cells after a 4 hour treatment with various concentrations (in nM) of BVD-523, dabrafenib (Dab), and Trametinib (Tram). 40 µg of total protein was loaded in each lane except where indicated otherwise. In this experiment, duplicate samples were collected. FIGS. 16A and 16B show results from duplicate samples. Similarly, FIGS. 16C and 16D also show results from duplicate samples. In FIGS. 16A and 16B, pRSK1 had a relatively weak signal in A375 cells compared to other markers. A different pRSK1-S380 antibody from Cell Signaling (cat. #11989) was tested but did not give a detectable signal (data not shown). In FIGS. 16C and 16D, pCRAF-338 gave a minimal signal.

[0034] FIGS. 17A-D are a set of images showing Western blot analysis of MAPK signaling in a human colorectal carcinoma cell line (HCT116 cells) after a 4 hour treatment with various concentrations (in nM) of BVD-523, dabrafenib (Dab), and Trametinib (Tram). 40 µg of total protein was loaded in each lane except where indicated otherwise. In this experiment, duplicate samples were collected. FIGS. 17A and 17B show results from duplicate samples. Similarly, FIGS. 17C and 17D also show results from duplicate samples. In FIGS. 17A-17B, pRSK1 levels appear to be very low in HCT116 cells, and in FIGS. 17C and 17D, pCRAF-338 signal was also very weak.

[0035] FIGS. 18A-D are a set of images showing Western blot analysis of cell cycle and apoptosis proteins in A375 melanoma cells after a 24 hour treatment with various concentrations (in nM) of BVD-523 ("BVD523"), trametinib ("tram") and/or dabrafenib ("Dab") as labelled. 50 µg of total protein was loaded in each lane except where indicated otherwise. In this experiment, duplicate samples were collected. FIGS. 18A and 18B show results from duplicate samples. Similarly, FIGS. 18C and

Date reçue/Date received 2024-05-31

18D also show results from duplicate samples. In FIGS. 18A and 18B, no band of a size corresponding to cleaved PARP (89 kDa) was apparent.

[0036] FIG. 19 is a histogram showing viability of A375 cells after 96 hours of incubation with various amounts of BVD-523 or BVD-523 in combination with 30 nM AZ628 (a RAF inhibitor) or 3 nM dabrafenib. The Bliss Scores are shown in the yellow boxes.

[0037] FIG. 20 is a histogram showing caspase activity in A375 cells after 24 hours of incubation with various amounts of BVD-523 or BVD-523 in combination with 30 nM AZ628 or 3 nM dabrafenib.

[0038] FIG. 21 is a histogram showing caspase activity in A375 cells after 48 hours of incubation with various amounts of BVD-523 or BVD-523 in combination with 30 nM AZ628 or 3 nM dabrafenib.

[0039] FIG. 22 is a histogram showing viability of HCT116 cells after 96 hours of incubation with various amounts of BVD-523 or BVD-523 in combination with 3 μM ABT-263. The Bliss Scores are shown in the yellow boxes.

[0040] FIG. 23 is a histogram showing caspase activity in HCT116 cells after 24 hours of incubation with various amounts of BVD-523 or BVD-523 in combination with 3 μM ABT-263.

[0041] FIG. 24 is a histogram showing caspase activity in HCT116 cells after 48 hours of incubation with various amounts of BVD-523 or BVD-523 in combination with 3 μM ABT-263.

[0042] FIG. 25 is a flowchart showing the dose escalation protocol used herein.

[0043] FIG. 26 shows the individual times to endpoint for mice in the study.

Date reçue/Date received 2024-05-31

[0044] FIG. 27 shows mean tumor growth (FIG. 27A) and Kaplan-Meier plot (FIG. 27B) for the study.

[0045] FIGS. 28A-28D show mean tumor growth for various groups of mice administered with dabrafenib/BVD-523 combinations compared to monotherapies.

[0046] FIG. 29 shows percent mean body weight changes from Day 1 in the *in vivo* study.

[0047] FIG. 30 shows a schematic of the mitogen-activated protein kinases (MAPK) pathway.

[0048] FIG. 31A is a dose matrix showing % inhibition of the AZ628/trametinib combination in HCT116 cells using the Alamar Blue cell viability assay. FIG. 31B is a dose matrix showing excess over Bliss for the AZ628/trametinib combination. FIGS. 31C and 31D show % viability relative to DMSO only treated controls for AZ628 and trametinib single agent treatments in HCT116 cells using the Alamar Blue cell viability assay. FIG. 31E shows % viability relative to DMSO only treated controls for AZ628/trametinib combination treatments in HCT116 cells using the Alamar Blue cell viability assay.

[0049] FIG. 32A is a dose matrix showing % inhibition of the AZ628/BVD-523 combination in HCT116 cells using the Alamar Blue cell viability assay. FIG. 32B is a dose matrix showing excess over Bliss for the AZ628/BVD-523 combination. FIGS. 32C and 32D show % viability relative to DMSO only treated controls for AZ628 and BVD-523 single agent treatments in HCT116 cells using the Alamar Blue cell viability assay. FIG. 32E shows % viability relative to DMSO only treated controls for AZ628/BVD-523 combination treatments in HCT116 cells using the Alamar Blue cell viability assay.

Date reçue/Date received 2024-05-31

[0050] FIG. 33A is a dose matrix showing % inhibition of the sorafenib/trametinib combination in HCT116 cells using the Alamar Blue cell viability assay. FIG. 33B is a dose matrix showing excess over Bliss for the sorafenib/trametinib combination. FIGS. 33C and 33D show % viability relative to DMSO only treated controls for sorafenib and trametinib single agent treatments in HCT116 cells using the Alamar Blue cell viability assay. FIG. 33E shows % viability relative to DMSO only treated controls for sorafenib/trametinib combination treatments in HCT116 cells using the Alamar Blue cell viability assay.

[0051] FIG. 34A is a dose matrix showing % inhibition of the sorafenib/BVD-523 combination in HCT116 cells using the Alamar Blue cell viability assay. FIG. 34B is a dose matrix showing excess over Bliss for the sorafenib/BVD-523 combination. FIGS. 34C and 34D show % viability relative to DMSO only treated controls for sorafenib and BVD-523 single agent treatments in HCT116 cells using the Alamar Blue cell viability assay. FIG. 34E shows % viability relative to DMSO only treated controls for sorafenib/BVD-523 combination treatments in HCT116 cells using the Alamar Blue cell viability assay.

[0052] FIG. 35A is a dose matrix showing % inhibition of the dabrafenib/trametinib combination in HCT116 cells using the Alamar Blue cell viability assay. FIG. 35B is a dose matrix showing excess over Bliss for the dabrafenib/trametinib combination. FIGS. 35C and 35D show % viability relative to DMSO only treated controls for dabrafenib and trametinib single agent treatments in HCT116 cells using the Alamar Blue cell viability assay. FIG. 35E shows % viability relative to DMSO only treated controls for dabrafenib/trametinib combination treatments in HCT116 cells using the Alamar Blue cell viability assay.

Date reçue/Date received 2024-05-31

[0053] FIG. 36A is a dose matrix showing % inhibition of the dabrafenib/BVD-523 combination in HCT116 cells using the Alamar Blue cell viability assay. FIG. 36B is a dose matrix showing excess over Bliss for the dabrafenib/BVD-523 combination. FIGS. 36C and 36D show % viability relative to DMSO only treated controls for dabrafenib and BVD-523 single agent treatments in HCT116 cells using the Alamar Blue cell viability assay. FIG. 36E shows % viability relative to DMSO only treated controls for dabrafenib/BVD-523 combination treatments in HCT116 cells using the Alamar Blue cell viability assay.

[0054] FIG. 37A is a dose matrix showing % inhibition of the AZ628/BVD-523 combination in A375 cells using the Alamar Blue cell viability assay. FIG. 37B is a dose matrix showing excess over Bliss for the AZ628/BVD-523 combination. FIGS. 37C and 37D show % viability relative to DMSO only treated controls for AZ628 and BVD-523 single agent treatments in A375 cells using the Alamar Blue cell viability assay. FIG. 37E shows % viability relative to DMSO only treated controls for AZ628/BVD-523 combination treatments in A375 cells using the Alamar Blue cell viability assay.

[0055] FIG. 38A is a dose matrix showing % inhibition of the sorafenib/trametinib combination in A375 cells using the Alamar Blue cell viability assay. FIG. 38B is a dose matrix showing excess over Bliss for the sorafenib/trametinib combination. FIGS. 38C and 38D show % viability relative to DMSO only treated controls for sorafenib and trametinib single agent treatments in A375 cells using the Alamar Blue cell viability assay. FIG. 38E shows % viability relative to DMSO only treated controls for sorafenib/trametinib combination treatments in A375 cells using the Alamar Blue cell viability assay.

Date reçue/Date received 2024-05-31

[0056] FIG. 39A is a dose matrix showing % inhibition of the sorafenib/BVD-523 combination in A375 cells using the Alamar Blue cell viability assay. FIG. 39B is a dose matrix showing excess over Bliss for the sorafenib/BVD-523 combination. FIGS. 39C and 39D show % viability relative to DMSO only treated controls for sorafenib and BVD-523 single agent treatments in A375 cells using the Alamar Blue cell viability assay. FIG. 39E shows % viability relative to DMSO only treated controls for sorafenib/BVD-523 combination treatments in A375 cells using the Alamar Blue cell viability assay.

[0057] FIG. 40A is a dose matrix showing % inhibition of the dabrafenib/trametinib combination in A375 cells using the Alamar Blue cell viability assay. FIG. 40B is a dose matrix showing excess over Bliss for the dabrafenib/trametinib combination. FIGS. 40C and 40D show % viability relative to DMSO only treated controls for dabrafenib and trametinib single agent treatments in A375 cells using the Alamar Blue cell viability assay. FIG. 40E shows % viability relative to DMSO only treated controls for dabrafenib/trametinib combination treatments in A375 cells using the Alamar Blue cell viability assay.

[0058] FIG. 41A is a dose matrix showing % inhibition of the dabrafenib/BVD-523 combination in A375 cells using the Alamar Blue cell viability assay. FIG. 41B is a dose matrix showing excess over Bliss for the dabrafenib/BVD-523 combination. FIGS. 41C and 41D show % viability relative to DMSO only treated controls for dabrafenib and BVD-523 single agent treatments in A375 cells using the Alamar Blue cell viability assay. FIG. 41E shows % viability relative to DMSO only treated controls for dabrafenib/BVD-523 combination treatments in A375 cells using the Alamar Blue cell viability assay.

Date reçue/Date received 2024-05-31

[0059] FIG. 42 shows results of single agent proliferation assays in A375 (FIG. 42A – FIG. 42F) and G-361 (FIG. 42G – FIG. 42L) cells. Prolifferation results are shown for treatment with Dabrafenib (FIG. 42A and FIG. 42G), Vemurafenib (FIG. 42B and FIG. 42H), TAK-632 (FIG. 42C and FIG. 42I), BVD-523 (FIG. 42D and FIG. 42J), SCH772984 (FIG. 42E and FIG. 42K), and Paclitaxel (FIG. 42F and FIG. 42L).

[0060] FIG. 43A is a dose matrix showing % inhibition of the Dabrafenib/BVD-523 combination in A375 cells. FIG. 43B is a dose matrix showing Loewe excess for the Dabrafenib/BVD-523 combination. FIG. 43C is a dose matrix showing Bliss excess for the Dabrafenib/BVD-523 combination. FIGS. 43D and 43E, respectively, show % viability relative to DMSO only treated controls for Dabrafenib and BVD-523 single agent treatments in A375 cells.

[0061] FIG. 44A is a dose matrix showing % inhibition of the Dabrafenib/SCH772984 combination in A375 cells. FIG. 43B is a dose matrix showing Loewe excess for the Dabrafenib/SCH772984 combination. FIG. 43C is a dose matrix showing Bliss excess for the Dabrafenib/SCH772984 combination. FIGS. 43D and 43E, respectively, show % viability relative to DMSO only treated controls for Dabrafenib and SCH772984 single agent treatments in A375 cells.

[0062] FIG. 45A is a dose matrix showing % inhibition of the Vemurafenib/BVD-523 combination in A375 cells. FIG. 45B is a dose matrix showing Loewe excess for the Vemurafenib/BVD-523 combination. FIG. 45C is a dose matrix showing Bliss excess for the Vemurafenib/BVD-523 combination. FIGS. 45D and 45E, respectively, show % viability relative to DMSO only treated controls for Vemurafenib and BVD-523 single agent treatments in A375 cells.

[0063] FIG. 46A is a dose matrix showing % inhibition of the Vemurafenib/SCH772984 combination in A375 cells. FIG. 46B is a dose matrix

Date reçue/Date received 2024-05-31

showing Loewe excess for the Vemurafenib/SCH772984 combination. FIG. 46C is a dose matrix showing Bliss excess for the Vemurafenib/SCH772984 combination. FIGS. 46D and 46E, respectively, show % viability relative to DMSO only treated controls for Vemurafenib and SCH772984 single agent treatments in A375 cells.

[0064] FIG. 47A is a dose matrix showing % inhibition of the TAK-632/BVD-523 combination in A375 cells. FIG. 47B is a dose matrix showing Loewe excess for the TAK-632/BVD-523 combination. FIG. 47C is a dose matrix showing Bliss excess for the TAK-632/BVD-523 combination. FIGS. 47D and 47E, respectively, show % viability relative to DMSO only treated controls for TAK-632 and BVD-523 single agent treatments in A375 cells.

[0065] FIG. 48A is a dose matrix showing % inhibition of the TAK-632/SCH772984 combination in A375 cells. FIG. 48B is a dose matrix showing Loewe excess for the TAK-632/SCH772984 combination. FIG. 48C is a dose matrix showing Bliss excess for the TAK-632/SCH772984 combination. FIGS. 48D and 48E, respectively, show % viability relative to DMSO only treated controls for TAK-632 and SCH772984 single agent treatments in A375 cells.

[0066] FIG. 49A is a dose matrix showing % inhibition of the Dabrafenib/BVD-523 combination in G-361 cells. FIG. 49B is a dose matrix showing Loewe excess for the Dabrafenib/BVD-523 combination. FIG. 49C is a dose matrix showing Bliss excess for the Dabrafenib/BVD-523 combination. FIGS. 49D and 49E, respectively, show % viability relative to DMSO only treated controls for Dabrafenib and BVD-523 single agent treatments in G-361 cells.

[0067] FIG. 50A is a dose matrix showing % inhibition of the Dabrafenib/SCH772984 combination in G-361 cells. FIG. 50B is a dose matrix showing Loewe excess for the Dabrafenib/SCH772984 combination. FIG. 50C is a

Date reçue/Date received 2024-05-31

dose matrix showing Bliss excess for the Dabrafenib/SCH772984 combination. FIGS. 50D and 50E, respectively, show % viability relative to DMSO only treated controls for Dabrafenib and SCH772984 single agent treatments in G-361 cells.

[0068] FIG. 51A is a dose matrix showing % inhibition of the Vemurafenib/BVD-523 combination in G-361 cells. FIG. 51B is a dose matrix showing Loewe excess for the Vemurafenib/BVD-523 combination. FIG. 51C is a dose matrix showing Bliss excess for the Vemurafenib/BVD-523 combination. FIGS. 51D and 51E, respectively, show % viability relative to DMSO only treated controls for Vemurafenib and BVD-523 single agent treatments in G-361 cells.

[0069] FIG. 52A is a dose matrix showing % inhibition of the Vemurafenib/SCH772984 combination in G-361 cells. FIG. 52B is a dose matrix showing Loewe excess for the Vemurafenib/SCH772984 combination. FIG. 52C is a dose matrix showing Bliss excess for the Vemurafenib/SCH772984 combination. FIGS. 52D and 52E, respectively, show % viability relative to DMSO only treated controls for Vemurafenib and SCH772984 single agent treatments in G-361 cells.

[0070] FIG. 53A is a dose matrix showing % inhibition of the TAK-632/BVD-523 combination in G-361 cells. FIG. 53B is a dose matrix showing Loewe excess for the TAK-632/BVD-523 combination. FIG. 53C is a dose matrix showing Bliss excess for the TAK-632/BVD-523 combination. FIGS. 53D and 53E, respectively, show % viability relative to DMSO only treated controls for TAK-632 and BVD-523 single agent treatments in G-361 cells.

[0071] FIG. 54A is a dose matrix showing % inhibition of the TAK-632/SCH772984 combination in G-361 cells. FIG. 54B is a dose matrix showing Loewe excess for the TAK-632/SCH772984 combination. FIG. 54C is a dose matrix showing Bliss excess for the TAK-632/SCH772984 combination. FIGS. 54D and

Date reçue/Date received 2024-05-31

54E, respectively, show % viability relative to DMSO only treated controls for TAK-632 and SCH772984 single agent treatments in G-361 cells.

[0072] FIG. 55A shows synergy scores for the tested combinations in both A375 and G-361 cells. FIG. 55B shows a graph of the values presented in FIG. 55A.

[0073] FIG. 56A shows Loewe volumes for the tested combinations in both A375 and G-361 cells. FIG. 56B shows a graph of the values presented in FIG. 56A.

[0074] FIG. 57A shows Bliss volumes for the tested combinations in both A375 and G-361 cells. FIG. 57B shows a graph of the values presented in FIG. 57A.

[0075] FIG. 58 shows the results of the combination of BVD-523 and SCH772984. FIG. 58A shows a dose matrix showing inhibition (%) for the combination in A375 cells. FIG. 58B – FIG. 58C show the results of single agent proliferation assays for the combination in 58A. FIG. 58D shows Loewe excess for the combination in 58A and FIG. 58E shows Bliss excess for the combination in 58A.

DETAILED DESCRIPTION OF THE INVENTION

[0076] One embodiment of the present invention is a method of treating or ameliorating the effects of a cancer in a subject in need thereof. This method comprises administering to the subject an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a type 1 RAF inhibitor or a pharmaceutically acceptable salt thereof, to treat or ameliorate the effects of the cancer.

[0077] As used herein, the terms "treat," "treating," "treatment" and grammatical variations thereof mean subjecting an individual subject to a protocol, regimen, process or remedy, in which it is desired to obtain a physiologic response or outcome in that subject, *e.g.*, a patient. In particular, the methods and compositions of the present invention may be used to slow the development of

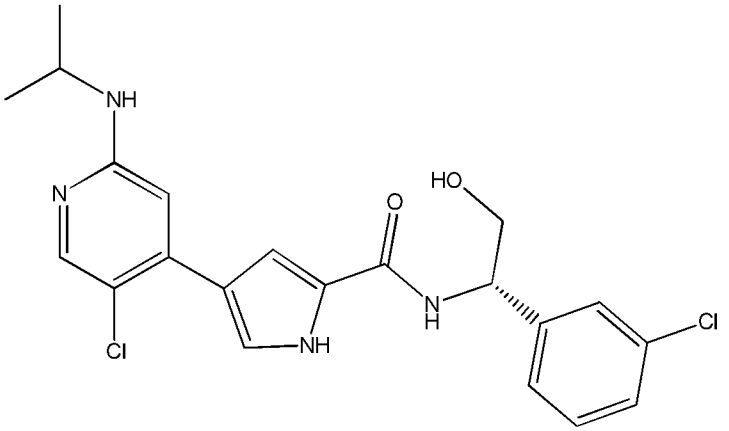
Date reçue/Date received 2024-05-31

disease symptoms or delay the onset of the disease or condition, or halt the progression of disease development. However, because every treated subject may not respond to a particular treatment protocol, regimen, process or remedy, treating does not require that the desired physiologic response or outcome be achieved in each and every subject or subject population, *e.g.*, patient population. Accordingly, a given subject or subject population, *e.g.*, patient population may fail to respond or respond inadequately to treatment.

[0078] As used herein, the terms “ameliorate”, "ameliorating" and grammatical variations thereof mean to decrease the severity of the symptoms of a disease in a subject.

[0079] As used herein, a “subject” is a mammal, preferably, a human. In addition to humans, categories of mammals within the scope of the present invention include, for example, farm animals, domestic animals, laboratory animals, etc. Some examples of farm animals include cows, pigs, horses, goats, etc. Some examples of domestic animals include dogs, cats, etc. Some examples of laboratory animals include primates, rats, mice, rabbits, guinea pigs, etc.

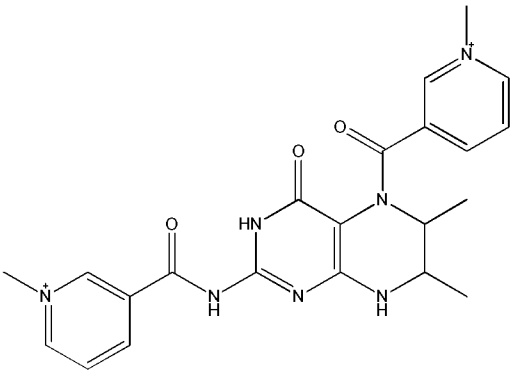
[0080] In the present invention, BVD-523 is a compound according to formula (I):



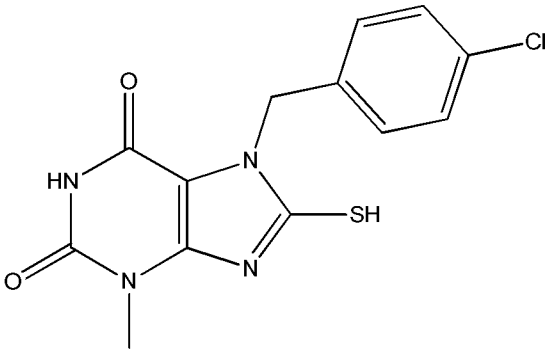
Date reçue/Date received 2024-05-31

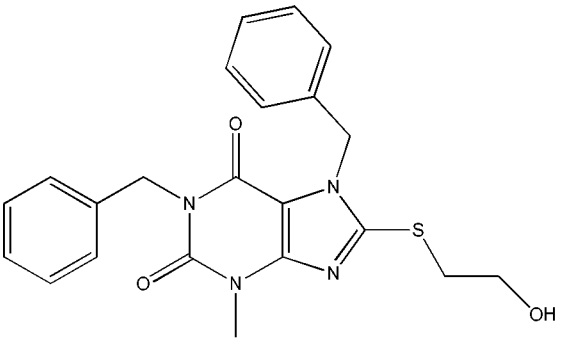
and pharmaceutically acceptable salts thereof. BVD-523 may be synthesized according to the methods disclosed in, *e.g.*, U.S. Patent No. 7,354,939. Enantiomers and racemic mixtures of both enantiomers of BVD-523 are also contemplated within the scope of the present invention. BVD-523 is an ERK1/2 inhibitor with a mechanism of action that is believed to be, *e.g.*, unique and distinct from certain other ERK1/2 inhibitors, such as SCH772984. For example, other ERK1/2 inhibitors, such as SCH772984, inhibit autophosphorylation of ERK (Morris *et al.*, 2013), whereas BVD-523 allows for the autophosphorylation of ERK while still inhibiting ERK (FIG. 18).

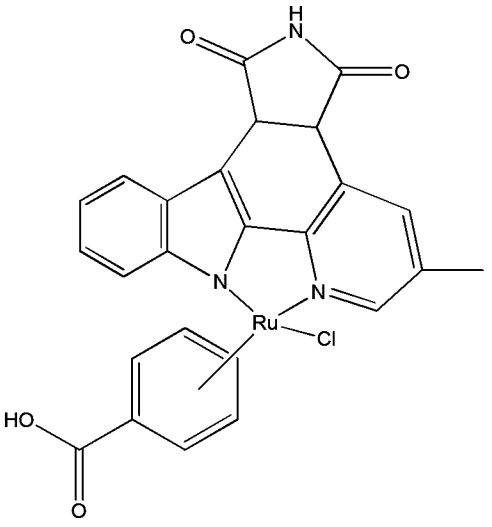
[0081] As used herein, a "RAF inhibitor" means those substances that (i) directly interact with RAF, *e.g.*, by binding to RAF and (ii) decrease the expression or the activity of RAF. RAF inhibitors may be classified into two types by their respective binding modes. As used herein, "Type 1" RAF inhibitors are those inhibitors that target the ATP binding sites of the kinase in its active conformation. "Type 2" RAF inhibitors are those inhibitors that preferentially bind to an inactive conformation of the kinase. Non-limiting examples of Type 1 RAF inhibitors include:

Compound 7  (Li *et al.*, 2010),

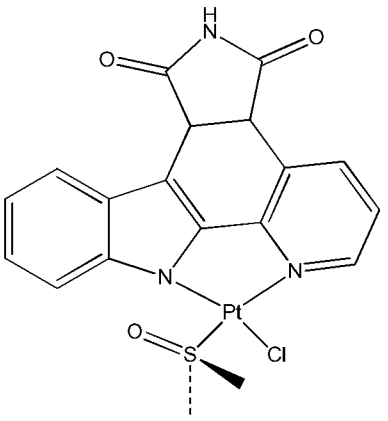
Date reçue/Date received 2024-05-31

Compound 9  (*Id.*),

Compound 10  (*Id.*),

Compound 13  (*Id.*),

Date reçue/Date received 2024-05-31



Compound 14 (*Id.*), dabrafenib (GlaxoSmithKline), GDC-0879 (Genentech), L-779450 B-Raf (Merck), PLX3202 (Plexxikon), PLX4720 (Plexxikon), SB-590885 (GlaxoSmithKline), SB-699393 (GlaxoSmithKline), vemurafenib (Plexxikon), pharmaceutically acceptable salts thereof, and combinations thereof. Preferably, the type 1 RAF inhibitor is dabrafenib or a pharmaceutically acceptable salt thereof.

[0082] In one aspect of this embodiment, the subject with cancer has a somatic BRAF mutation or is refractory to MAPK pathway inhibitor treatment. Preferably, the subject is refractory to non-ERK MAPK pathway inhibitor treatment.

[0083] As used herein, "somatic mutation" means a change occurring in any cell that is not destined to become a germ cell. The mutation may be, *e.g.*, a substitution, deletion, insertion, or a fusion. Table 1 below shows a distribution overview of BRAF mutations, as shown in the Sanger database.

Table 1 - Distribution overview of BRAF mutations

Mutation Type	Mutant samples	Percentage
Substitution nonsense	23	0.07
Substitution missense	32955	99.07
Substitution synonymous	80	0.24
Insertion inframe	25	0.08
Insertion frameshift	1	0.00
Deletion inframe	13	0.04

Date reçue/Date received 2024-05-31

Mutation Type	Mutant samples	Percentage
Deletion frameshift	5	0.02
Complex	39	0.12
Other	172	0.52
Total	33263	100

[0084] BRAF mutations are found in approximately 66% melanoma (Davies *et al.*, 2002; Brose *et al.*, 2002; Hocket *et al.*, 2007), and a relatively lower percentage in other cancers, 36% thyroid tumors and 10% colon cancers (Xu *et al.*, 2003; Fransen *et al.*, 2004). The most prevalent BRAF mutation occurs at amino acid 600 of the wild-type protein kinase (SEQ ID NO:2) by substituting valine with glutamic acid resulting in the mutant B-RafV600E, which accounts for about 80% of BRAF mutations (Davies *et al.*, 2002; Hocker *et al.*, 2007). B-RafV600E kinase domain has 500-fold higher kinase activity compared to the basal activity of wild-type B-Raf (Wan *et al.*, 2004). Of the other BRAF mutations identified in melanoma, V600K and V600D/R are also common and represent 16% and 3% of all BRAF mutations, respectively (Long *et al.*, 2011). In addition to melanoma, BRAF mutations are also common in many other cancers including papillary thyroid carcinoma, ovarian carcinoma, and colorectal carcinoma. (Wellbrock *et al.*, 2004). In one study, BRAF splice variants (splicing out exons 14 and 15) were found in 5/24 (21%) colorectal cancers cell lines (Seth *et al.*, 2009).

[0085] Table 2 below from the Sanger database shows the distribution and frequency of BRAF mutations in human tumors.

Table 2

Primary Tissue	Unique Mutated Samples	Total Unique Samples	% Mutated
NS	1071	1788	59.90
Adrenal gland	3	155	1.94

Date reçue/Date received 2024-05-31

Primary Tissue	Unique Mutated Samples	Total Unique Samples	% Mutated
Autonomic ganglia	3	703	0.43
Biliary tract	36	684	5.26
Bone	5	284	1.76
Breast	27	2297	1.18
Central nervous system	206	3297	6.25
Cervix	6	473	1.27
Endometrium	40	2510	1.59
Eye	70	732	9.56
Fallopian tube	0	2	0
Gastrointestinal tract (site indeterminate)	5	514	0.97
Genital tract	4	54	7.41
Haematopoietic and lymphoid tissue	507	5388	9.41
Kidney	34	959	3.55
Large intestine	8301	67530	12.29
Liver	18	618	2.91
Lung	293	11249	2.60
Meninges	0	74	0
Oesophagus	5	927	0.54
Ovary	312	3922	7.96
Pancreas	16	1089	1.47
Parathyroid	0	20	0
Penis	0	28	0
Peritoneum	0	37	0
Pituitary	1	115	0.87
Placenta	0	2	0
Pleura	3	148	2.03
Prostate	25	1483	1.69
Salivary gland	1	131	0.76
Skin	7245	16943	42.76
Small intestine	12	251	4.78
Soft tissue	45	2160	2.08
Stomach	11	1473	0.75
Testis	7	251	2.79
Thymus	0	50	0
Thyroid	14929	38002	39.28
Upper aerodigestive tract	14	1352	1.04
Urinary tract	8	612	1.31
Vagina	0	1	0
Vulva	0	3	0
Total	33263	168311	19.76

Date reçue/Date received 2024-05-31

[0086] Table 3 below shows select nucleic acid and amino acid sequences of BRAF. These sequences may be used in methods for identifying subjects with a mutant BRAF genotype (such as in the methods set forth below).

Table 3

SEQ ID NO	Nucleic acid or polypeptide	Organism	Other information
1	nucleic acid	human	
2	polypeptide	human	
3	nucleic acid	rat (Rattus norvegicus)	
4	polypeptide	rat (Rattus norvegicus)	
5	nucleic acid	mouse, Mus musculus	
6	polypeptide	mouse, Mus musculus	
7	nucleic acid	rabbit, Oryctolagus cuniculus	
8	polypeptide	rabbit, Oryctolagus cuniculus	
9	nucleic acid	guinea pig, Cavia porcellus	
10	polypeptide	guinea pig, Cavia porcellus	
11	nucleic acid	dog, Canis lupus familiaris	variant x1
12	polypeptide	dog, Canis lupus familiaris	variant x1
13	nucleic acid	dog, Canis lupus familiaris	variant x2
14	polypeptide	dog, Canis lupus familiaris	variant x2
15	nucleic acid	cat, Felis catus	
16	polypeptide	cat, Felis catus	
17	nucleic acid	cow, Bos taurus	variant X1
18	polypeptide	cow, Bos taurus	variant X1
19	nucleic acid	cow, Bos taurus	variant X2
20	polypeptide	cow, Bos taurus	variant X2
21	nucleic acid	cow, Bos taurus	variant X3
22	polypeptide	cow, Bos taurus	variant X3
23	nucleic acid	cow, Bos taurus	variant X4
24	polypeptide	cow, Bos taurus	variant X4
25	nucleic acid	cow, Bos taurus	variant X5
26	polypeptide	cow, Bos taurus	variant X5
27	nucleic acid	cow, Bos taurus	variant X6
28	polypeptide	cow, Bos taurus	variant X6
29	nucleic acid	cow, Bos taurus	variant X7
30	polypeptide	cow, Bos taurus	variant X7
31	nucleic acid	cow, Bos taurus	variant X8
32	polypeptide	cow, Bos taurus	variant X8
33	nucleic acid	cow, Bos taurus	variant X9
34	polypeptide	cow, Bos taurus	variant X9
35	nucleic acid	cow, Bos taurus	variant X10

Date reçue/Date received 2024-05-31

SEQ ID NO	Nucleic acid or polypeptide	Organism	Other information
36	polypeptide	cow, Bos taurus	variant X10
37	nucleic acid	cow, Bos taurus	variant X11
38	polypeptide	cow, Bos taurus	variant X11
39	nucleic acid	cow, Bos taurus	variant 2
40	polypeptide	cow, Bos taurus	variant 2
41	nucleic acid	horse, Equus caballus	
42	polypeptide	horse, Equus caballus	
43	nucleic acid	chicken, Gallus gallus	
44	polypeptide	chicken, Gallus gallus	

[0087] Methods for identifying mutations in nucleic acids, such as the above identified BRAF genes, are known in the art. Nucleic acids may be obtained from biological samples. In the present invention, biological samples include, but are not limited to, blood, plasma, urine, skin, saliva, and biopsies. Biological samples are obtained from a subject by routine procedures and methods which are known in the art.

[0088] Non-limiting examples of methods for identifying mutations include PCR, sequencing, hybrid capture, in-solution capture, molecular inversion probes, fluorescent in situ hybridization (FISH) assays, and combinations thereof.

[0089] Various sequencing methods are known in the art. These include, but are not limited to, Sanger sequencing (also referred to as dideoxy sequencing) and various sequencing-by-synthesis (SBS) methods as disclosed in, *e.g.*, Metzker 2005, sequencing by hybridization, by ligation (for example, WO 2005021786), by degradation (for example, U.S. Patent Nos. 5,622,824 and 6,140,053) and nanopore sequencing (which is commercially available from Oxford Nanopore Technologies, UK). In deep sequencing techniques, a given nucleotide in the sequence is read more than once during the sequencing process. Deep sequencing techniques are

Date reçue/Date received 2024-05-31

disclosed in *e.g.*, U.S. Patent Publication No. 20120264632 and International Patent Publication No. WO2012125848.

[0090] The PCR-based methods for detecting mutations are known in the art and employ PCR amplification, where each target sequence in the sample has a corresponding pair of unique, sequence-specific primers. For example, the polymerase chain reaction-restriction fragment length polymorphism (PCR-RFLP) method allows for rapid detection of mutations after the genomic sequences are amplified by PCR. The mutation is discriminated by digestion with specific restriction endonucleases and is identified by electrophoresis. *See, e.g.*, Ota *et al.*, 2007. Mutations may also be detected using real time PCR. *See, e.g.*, International Application publication No. WO2012046981.

[0091] Hybrid capture methods are known in the art and are disclosed in, *e.g.*, U.S. Patent Publication No. 20130203632 and U.S. Patent Nos. 8,389,219 and 8,288,520. These methods are based on the selective hybridization of the target genomic regions to user-designed oligonucleotides. The hybridization can be to oligonucleotides immobilized on high or low density microarrays (on-array capture), or solution-phase hybridization to oligonucleotides modified with a ligand (*e.g.* biotin) which can subsequently be immobilized to a solid surface, such as a bead (in-solution capture).

[0092] Molecular Inversion Probe (MIP) methods are known in the art and are disclosed in *e.g.*, Absalan *et al.*, 2008. Such methods use MIP molecules, which are special "padlock" probes (Nilsson *et al.*, 1994) for genotyping. A MIP molecule is a linear oligonucleotide that contains specific regions, universal sequences, restriction sites and a Tag (index) sequence (16-22 bp). In such methods, a MIP hybridizes directly around the genetic marker/SNP of interest. The MIP method may also use a

Date reçue/Date received 2024-05-31

number of "padlock" probe sets that hybridize to genomic DNA in parallel (Hardenbol *et al.*, 2003). In case of a perfect match, genomic homology regions are ligated by undergoing an inversion in configuration (as suggested by the name of the technique) and creating a circular molecule. After the first restriction, all molecules are amplified with universal primers. Amplicons are restricted again to ensure short fragments for hybridization on a microarray. Generated short fragments are labeled and, through a Tag sequence, hybridized to a cTag (complementary strand for index) on an array. After the formation of a Tag-cTag duplex, a signal is detected.

[0093] As used herein, being “refractory” to MAPK pathway inhibitor treatment means that one or more MAPK pathway inhibitors has reduced efficacy in treating cancer.

[0094] As used herein, a “mitogen-activated protein kinase (MAPK) pathway inhibitor” is any substance that reduces the activity, expression or phosphorylation of proteins in the MAPK pathway that result in a reduction of cell growth or an increase in cell death.

[0095] An overview of the mammalian MAPK cascades is shown in FIG. 30. The details of the MAPK pathways are reviewed in *e.g.*, Akinleye *et al.*, 2013. Briefly, with respect to the ERK1/2 module in FIG. 30 (light purple box), the MAPK 1/2 signaling cascade is activated by ligand binding to receptor tyrosine kinases (RTK). The activated receptors recruit and phosphorylate adaptor proteins Grb2 and SOS, which then interact with membrane-bound GTPase Ras and cause its activation. In its activated GTP-bound form, Ras recruits and activates Raf kinases (A-Raf, B-Raf, and C-Raf/RaF-1). The activated Raf kinases activate MAPK 1/2 (MKK1/2), which in turn catalyzes the phosphorylation of threonine and tyrosine residues in the activation sequence Thr-Glu-Tyr of ERK1/2. With respect to the

Date reçue/Date received 2024-05-31

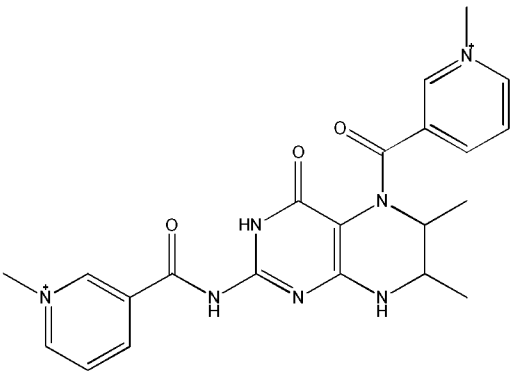
JNK/p38 module (yellow box in FIG. 30), upstream kinases, MAP3Ks, such as MEKK1/4, ASK1/2, and MLK1/2/3, activate MAP2K3/6 (MKK3/6), MAP2K4 (MKK4), and MAP2K7 (MKK7). These MAP2Ks then activate JNK protein kinases, including JNK1, JNK2, and JNK3, as well as p38 α/β/γ/δ. To execute their functions, JNKs activate several transcription factors, including c-Jun, ATF-2, NF-ATc1, HSF-1 and STAT3. With respect to the ERK5 module (blue box in FIG. 30), the kinases upstream of MAP2K5 (MKK5) are MEKK2 and MEKK3. The best characterized downstream target of MEK5 is ERK5, also known as big MAP kinase 1 (BMK1) because it is twice the size of other MAPKs.

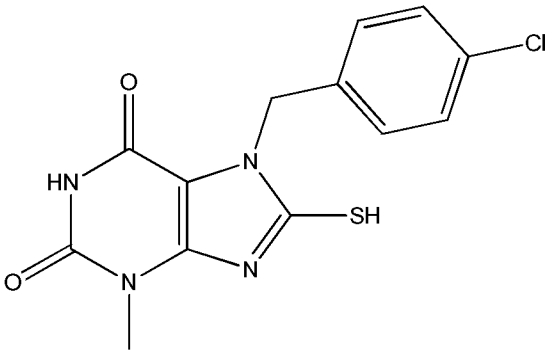
[0096] Non-limiting examples of MAPK pathway inhibitors include RAS inhibitors, RAF inhibitors, MEK inhibitors, ERK1/2 inhibitors, pharmaceutically acceptable salts thereof, and combinations thereof.

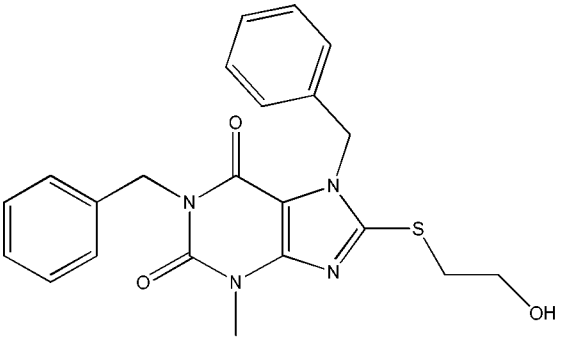
[0097] As used herein, a "RAS inhibitor" means those substances that (i) directly interact with RAS, *e.g.*, by binding to RAS and (ii) decrease the expression or the activity of RAS. Non-limiting exemplary RAS inhibitors include, but are not limited to, farnesyl transferase inhibitors (such as, *e.g.*, tipifarnib and lonafarnib), farnesyl group-containing small molecules (such as, *e.g.*, salirasib and TLN-4601), DCAI, as disclosed by Maurer (Maurer *et al.*, 2012), Kobe0065 and and Kobe2602, as disclosed by Shima (Shima *et al.*, 2013), HBS 3 (Patgiri *et al.*, 2011), and AIK-4 (Allinky).

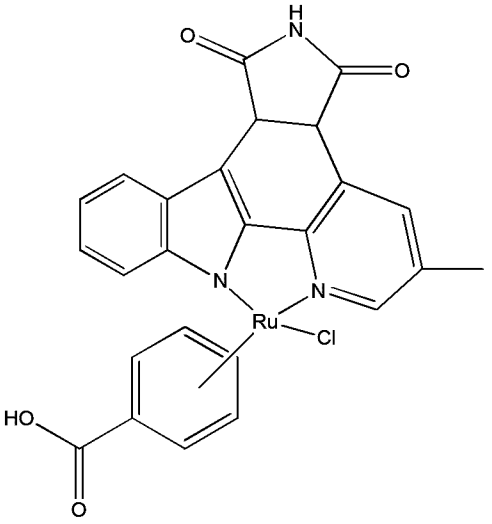
[0098] As used herein, a "RAF inhibitor" means those substances that (i) directly interact with RAF, *e.g.*, by binding to RAF and (ii) decrease the expression or the activity of RAF, such as, *e.g.*, A-RAF, B-RAF, and C-RAF (Raf-1). Non-limiting exemplary RAF inhibitors include:

Date reçue/Date received 2024-05-31

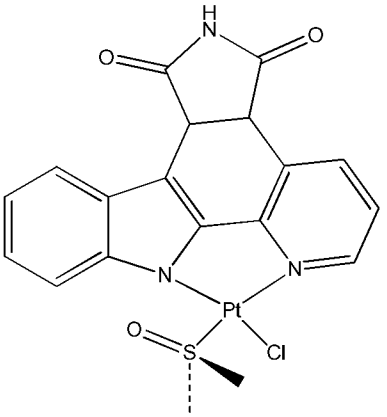
Compound 7  (Li *et al.*, 2010),

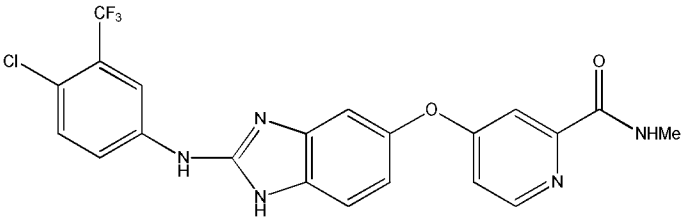
Compound 9  (*Id.*),

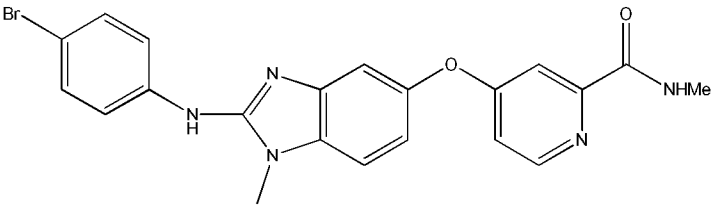
Compound 10  (*Id.*),

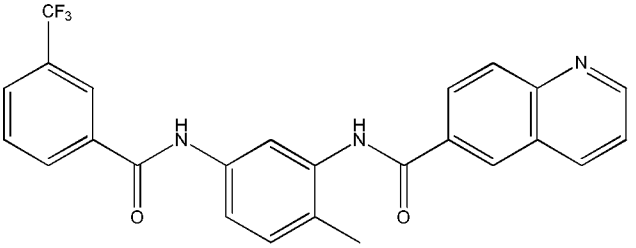
Compound 13  (*Id.*),

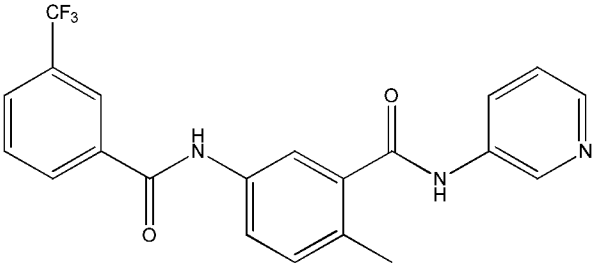
Date reçue/Date received 2024-05-31

Compound 14  (*Id.*),

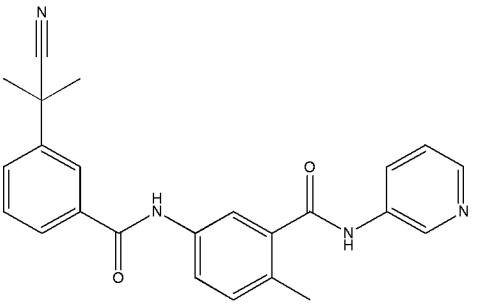
Compound 15  (*Id.*),

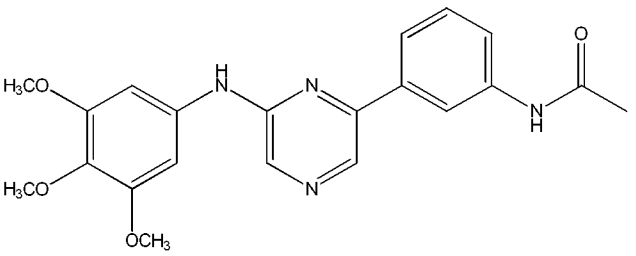
Compound 16  (*Id.*),

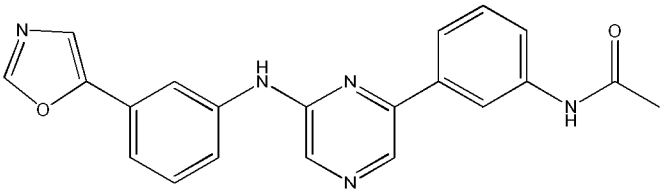
Compound 18  (*Id.*),

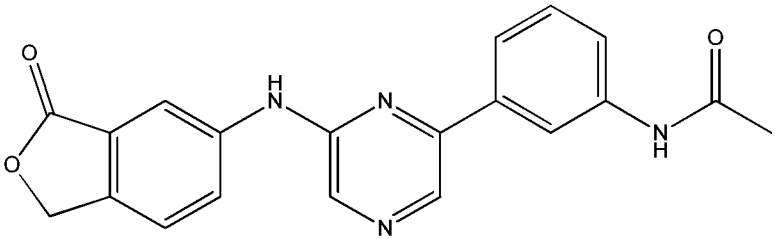
Compound 19  (*Id.*),

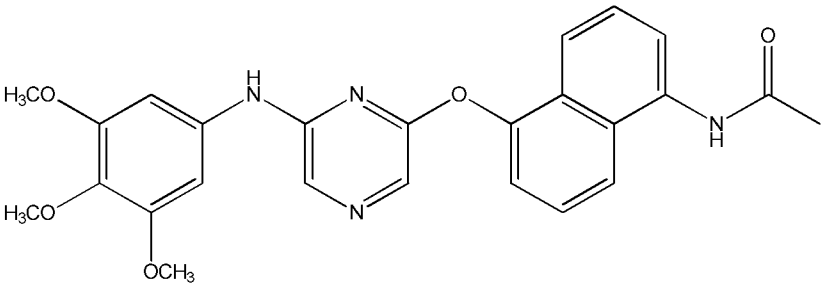
Date reçue/Date received 2024-05-31

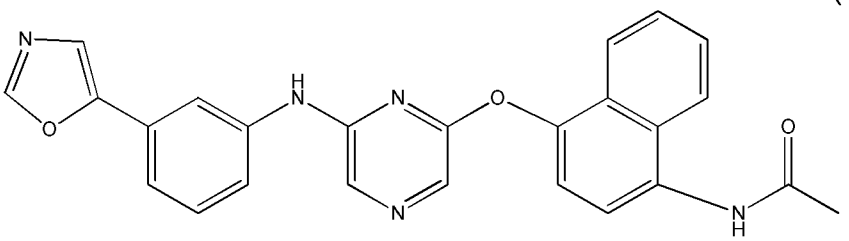
Compound 20  (*Id.*),

Compound 21  (*Id.*),

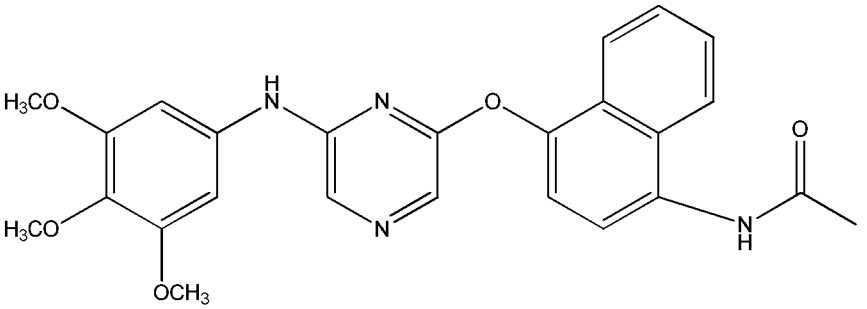
Compound 22  (*Id.*),

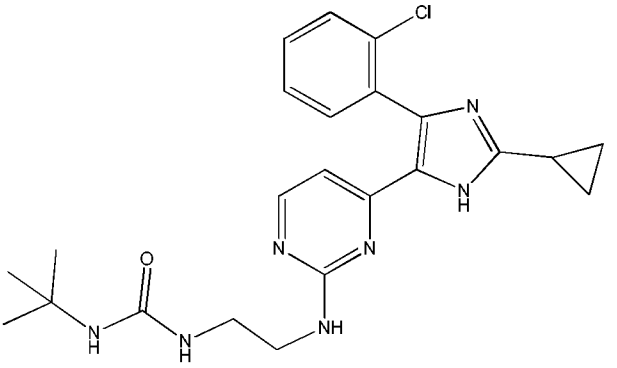
Compound 23  (*Id.*),

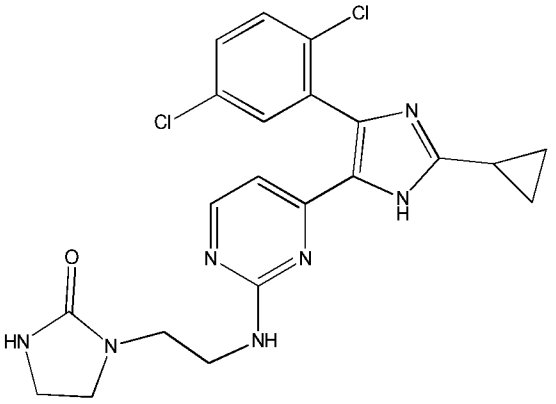
Compound 24  (*Id.*),

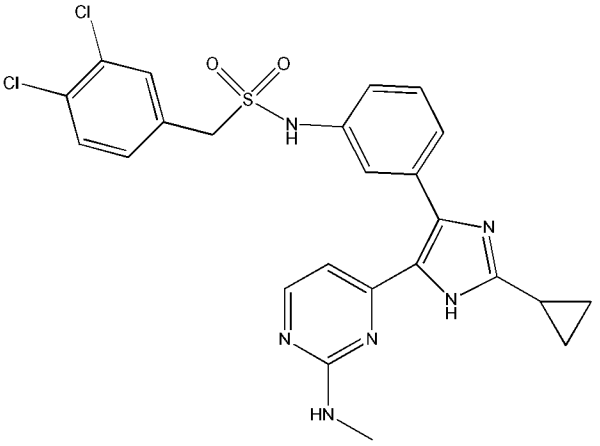
Compound 25  (*Id.*),

Date reçue/Date received 2024-05-31

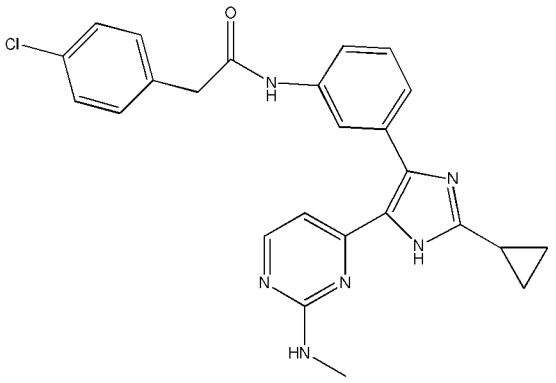
Compound 26 

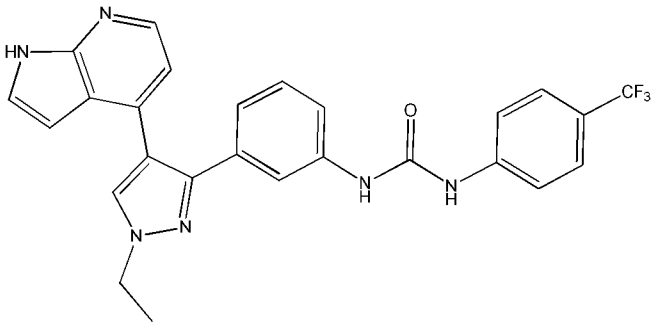
(*Id.*), Compound 27  (*Id.*),

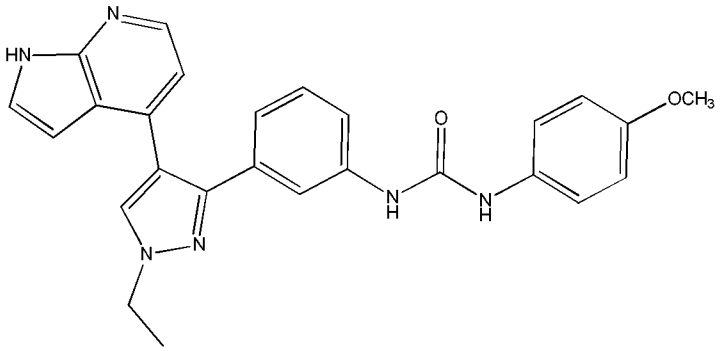
Compound 28  (*Id.*),

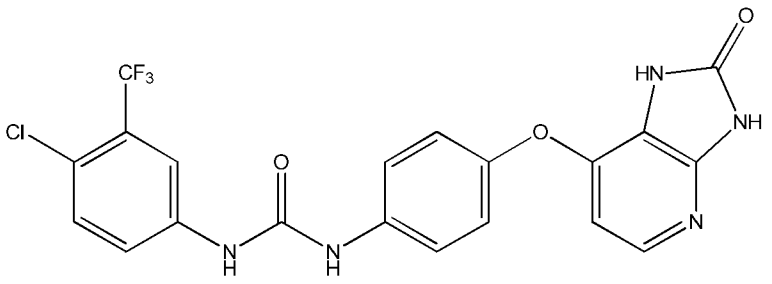
Compound 30  (*Id.*),

Date reçue/Date received 2024-05-31

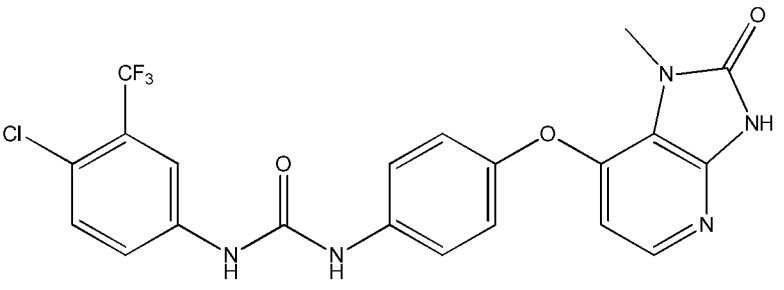
Compound 31  (*Id.*),

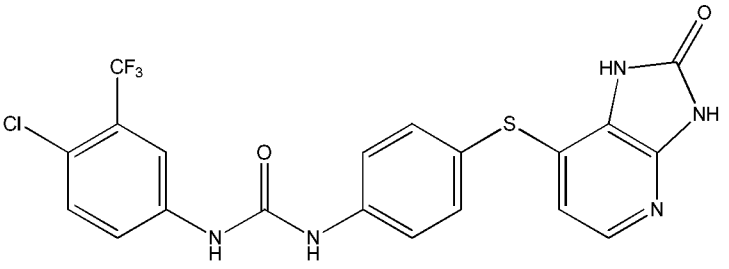
Compound 32  (*Id.*),

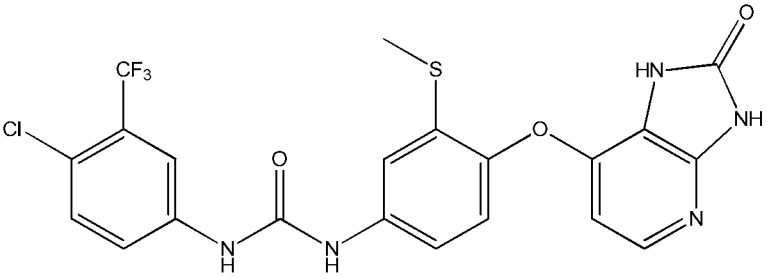
Compound 33  (*Id.*),

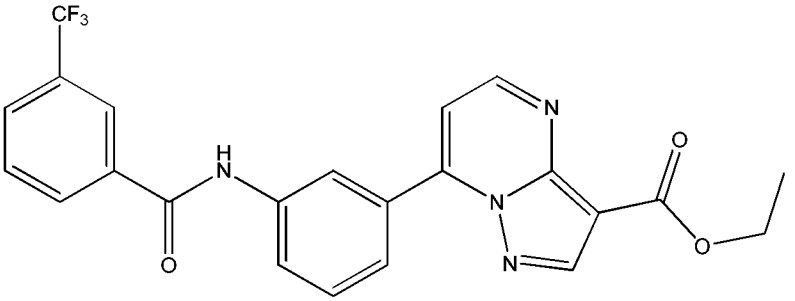
Compound 34  (*Id.*),

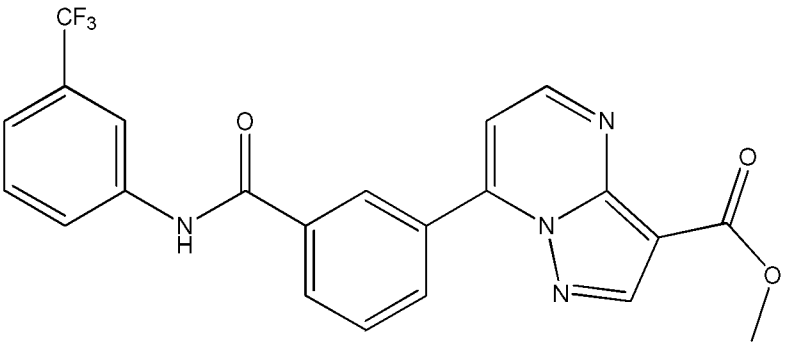
Date reçue/Date received 2024-05-31

Compound 35  (*Id.*),

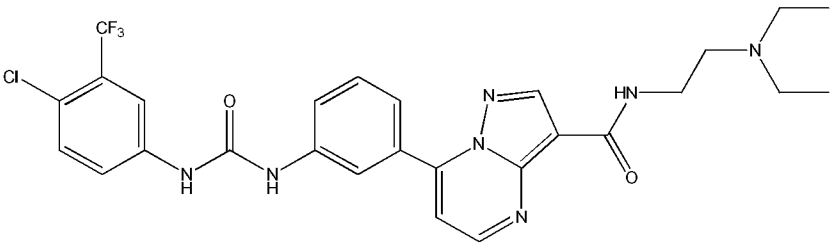
Compound 36  (*Id.*),

Compound 37  (*Id.*),

Compound 38  (*Id.*),

Compound 39  (*Id.*),

Date reçue/Date received 2024-05-31



Compound 40 (*Id.*),

AAL881 (Novartis); AB-024 (Ambit Biosciences), ARQ-736 (ArQule), ARQ-761 (ArQule), AZ628 (Axon Medchem BV), BeiGene-283 (BeiGene), BIIB-024 (MLN 2480) (Sunesis & Takeda), b-raf inhibitor (Sareum), BRAF kinase inhibitor (Selexagen Therapeutics), BRAF siRNA 313 (tacaccagcaagctagatgca) and 523 (cctatcgttagagtcttcctg) (Liu *et al.*, 2007), CTT239065 (Institute of Cancer Research), dabrafenib (GSK2118436), DP-4978 (Deciphera Pharmaceuticals), HM-95573 (Hanmi), GDC-0879 (Genentech), GW-5074 (Sigma Aldrich), ISIS 5132 (Novartis), L779450 (Merck), LBT613 (Novartis), LErafAON (NeoPharm, Inc.), LGX-818 (Novartis), pazopanib (GlaxoSmithKline), PLX3202 (Plexxikon), PLX4720 (Plexxikon), PLX5568 (Plexxikon), RAF-265 (Novartis), RAF-365 (Novartis), regorafenib (Bayer Healthcare Pharmaceuticals, Inc.), RO 5126766 (Hoffmann-La Roche), SB-590885 (GlaxoSmithKline), SB699393 (GlaxoSmithKline), sorafenib (Onyx Pharmaceuticals), TAK 632 (Takeda), TL-241 (Teligene), vemurafenib (RG7204 or PLX4032) (Daiichi Sankyo), XL-281 (Exelixis), ZM-336372 (AstraZeneca), pharmaceutically acceptable salts thereof, and combinations thereof.

[0099] As used herein, a “MEK inhibitor” means those substances that (i) directly interact with MEK, *e.g.*, by binding to MEK and (ii) decrease the expression or the activity of MEK. Thus, inhibitors that act upstream of MEK, such as RAS inhibitors and RAF inhibitors, are not MEF inhibitors according to the present invention. Non-limiting examples of MEK inhibitors include anthrax toxin, antroquinonol (Golden Biotechnology), ARRY-142886 (6-(4-bromo-2-chloro-

Date reçue/Date received 2024-05-31

phenylamino)-7-fluoro-3-methyl-3H-benzoimidazole-5-carboxylic acid (2-hydroxy-ethoxy)-amide) (Array BioPharma), ARRY-438162 (Array BioPharma), AS-1940477 (Astellas), AS-703988 (Merck KGaA), bentamapimod (Merck KGaA), BI-847325 (Boehringer Ingelheim), E-6201 (Eisai), GDC-0623 (Hoffmann-La Roche), GDC-0973 (cobimetinib) (Hoffmann-La Roche), L783277 (Merck), lethal factor portion of anthrax toxin, MEK162 (Array BioPharma), PD 098059 (2-(2'-amino-3'-methoxyphenyl)-oxanaphthalen-4-one) (Pfizer), PD 184352 (CI-1040) (Pfizer), PD-0325901 (Pfizer), pimasertib (Santhera Pharmaceuticals), RDEA119 (Ardea Biosciences/Bayer), refametinib (AstraZeneca), RG422 (Chugai Pharmaceutical Co.), RO092210 (Roche), RO4987655 (Hoffmann-La Roche), RO5126766 (Hoffmann-La Roche), selumetinib (AZD6244) (AstraZeneca), SL327 (Sigma), TAK-733 (Takeda), trametinib (Japan Tobacco), U0126 (1,4-diamino-2,3-dicyano-1,4-bis(2-aminophenylthio)butadiene) (Sigma), WX-554 (Wilex), YopJ polypeptide (Mittal *et al.*, 2010), pharmaceutically acceptable salts thereof, and combinations thereof.

[0100] As used herein, an "ERK1/2 inhibitor" means those substances that (i) directly interact with ERK1 and/or ERK2, *e.g.*, by binding to ERK1/2 and (ii) decrease the expression or the activity of ERK1 and/or ERK2 protein kinases. Therefore, inhibitors that act upstream of ERK1/2, such as MEK inhibitors and RAF inhibitors, are not ERK1/2 inhibitors according to the present invention. Non-limiting examples of an ERK1/2 inhibitor include AEZS-131 (Aeterna Zentaris), AEZS-136 (Aeterna Zentaris), BVD-523, SCH-722984 (Merck & Co.), SCH-772984 (Merck & Co.), SCH-900353 (MK-8353) (Merck & Co.), pharmaceutically acceptable salts thereof, and combinations thereof.

[0101] In another aspect of this embodiment, the method further comprises administering to the subject at least one additional therapeutic agent effective for

Date reçue/Date received 2024-05-31

treating or ameliorating the effects of the cancer. The additional therapeutic agent may be selected from the group consisting of an antibody or fragment thereof, a cytotoxic agent, a toxin, a radionuclide, an immunomodulator, a photoactive therapeutic agent, a radiosensitizing agent, a hormone, an anti-angiogenesis agent, and combinations thereof.

[0102] As used herein, an “antibody” encompasses naturally occurring immunoglobulins as well as non-naturally occurring immunoglobulins, including, for example, single chain antibodies, chimeric antibodies (e.g., humanized murine antibodies), and heteroconjugate antibodies (e.g., bispecific antibodies). Fragments of antibodies include those that bind antigen, (e.g., Fab', F(ab')2, Fab, Fv, and rIgG). See also, e.g., Pierce Catalog and Handbook, 1994-1995 (Pierce Chemical Co., Rockford, Ill.); Kuby, J., Immunology, 3rd Ed., W.H. Freeman & Co., New York (1998). The term antibody also includes bivalent or bispecific molecules, diabodies, triabodies, and tetrabodies. The term "antibody" further includes both polyclonal and monoclonal antibodies.

[0103] Examples of therapeutic antibodies that may be used in the present invention include rituximab (Rituxan), Cetuximab (Erbitux), bevacizumab (Avastin), and Ibritumomab (Zevalin).

[0104] Cytotoxic agents according to the present invention include DNA damaging agents, antimetabolites, anti-microtubule agents, antibiotic agents, etc. DNA damaging agents include alkylating agents, platinum-based agents, intercalating agents, and inhibitors of DNA replication. Non-limiting examples of DNA alkylating agents include cyclophosphamide, mechlorethamine, uramustine, melphalan, chlorambucil, ifosfamide, carmustine, lomustine, streptozocin, busulfan, temozolomide, pharmaceutically acceptable salts thereof, prodrugs, and

Date reçue/Date received 2024-05-31

combinations thereof. Non-limiting examples of platinum-based agents include cisplatin, carboplatin, oxaliplatin, nedaplatin, satraplatin, triplatin tetranitrate, pharmaceutically acceptable salts thereof, prodrugs, and combinations thereof. Non-limiting examples of intercalating agents include doxorubicin, daunorubicin, idarubicin, mitoxantrone, pharmaceutically acceptable salts thereof, prodrugs, and combinations thereof. Non-limiting examples of inhibitors of DNA replication include irinotecan, topotecan, amsacrine, etoposide, etoposide phosphate, teniposide, pharmaceutically acceptable salts thereof, prodrugs, and combinations thereof. Antimetabolites include folate antagonists such as methotrexate and premetrexed, purine antagonists such as 6-mercaptopurine, dacarbazine, and fludarabine, and pyrimidine antagonists such as 5-fluorouracil, arabinosylcytosine, capecitabine, gemcitabine, decitabine, pharmaceutically acceptable salts thereof, prodrugs, and combinations thereof. Anti-microtubule agents include without limitation vinca alkaloids, paclitaxel (Taxol®), docetaxel (Taxotere®), and ixabepilone (Ixempra®). Antibiotic agents include without limitation actinomycin, anthracyclines, valrubicin, epirubicin, bleomycin, plicamycin, mitomycin, pharmaceutically acceptable salts thereof, prodrugs, and combinations thereof.

[0105] Cytotoxic agents according to the present invention also include an inhibitor of the PI3K/Akt pathway. Non-limiting examples of an inhibitor of the PI3K/Akt pathway include A-674563 (CAS # 552325-73-2), AGL 2263, AMG-319 (Amgen, Thousand Oaks, CA), AS-041164 (5-benzo[1,3]dioxol-5-ylmethylene-thiazolidine-2,4-dione), AS-604850 (5-(2,2-Difluoro-benzo[1,3]dioxol-5-ylmethylene)-thiazolidine-2,4-dione), AS-605240 (5-quinoxilin-6-methylene-1,3-thiazolidine-2,4-dione), AT7867 (CAS # 857531-00-1), benzimidazole series, Genentech (Roche Holdings Inc., South San Francisco, CA), BML-257 (CAS # 32387-96-5), CAL-120

Date reçue/Date received 2024-05-31

(Gilead Sciences, Foster City, CA), CAL-129 (Gilead Sciences), CAL-130 (Gilead Sciences), CAL-253 (Gilead Sciences), CAL-263 (Gilead Sciences), CAS # 612847-09-3, CAS # 681281-88-9, CAS # 75747-14-7, CAS # 925681-41-0, CAS # 98510-80-6, CCT128930 (CAS # 885499-61-6), CH5132799 (CAS # 1007207-67-1), CHR-4432 (Chroma Therapeutics, Ltd., Abingdon, UK), FPA 124 (CAS # 902779-59-3), GS-1101 (CAL-101) (Gilead Sciences), GSK 690693 (CAS # 937174-76-0), H-89 (CAS # 127243-85-0), Honokiol, IC87114 (Gilead Science), IPI-145 (Intellikine Inc.), KAR-4139 (Karus Therapeutics, Chilworth, UK), KAR-4141 (Karus Therapeutics), KIN-1 (Karus Therapeutics), KT 5720 (CAS # 108068-98-0), Miltefosine, MK-2206 dihydrochloride (CAS # 1032350-13-2), ML-9 (CAS # 105637-50-1), Naltrindole Hydrochloride, OXY-111A (NormOxys Inc., Brighton, MA), perifosine, PHT-427 (CAS # 1191951-57-1), PI3 kinase delta inhibitor, Merck KGaA (Merck & Co., Whitehouse Station, NJ), PI3 kinase delta inhibitors, Genentech (Roche Holdings Inc.), PI3 kinase delta inhibitors, Incozen (Incozen Therapeutics, Pvt. Ltd., Hydrabad, India), PI3 kinase delta inhibitors-2, Incozen (Incozen Therapeutics), PI3 kinase inhibitor, Roche-4 (Roche Holdings Inc.), PI3 kinase inhibitors, Roche (Roche Holdings Inc.), PI3 kinase inhibitors, Roche-5 (Roche Holdings Inc.), PI3-alpha/delta inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd., South San Francisco, CA), PI3-delta inhibitors, Cellzome (Cellzome AG, Heidelberg, Germany), PI3-delta inhibitors, Intellikine (Intellikine Inc., La Jolla, CA), PI3-delta inhibitors, Pathway Therapeutics-1 (Pathway Therapeutics Ltd.), PI3-delta inhibitors, Pathway Therapeutics-2 (Pathway Therapeutics Ltd.), PI3-delta/gamma inhibitors, Cellzome (Cellzome AG), PI3-delta/gamma inhibitors, Cellzome (Cellzome AG), PI3-delta/gamma inhibitors, Intellikine (Intellikine Inc.), PI3-delta/gamma inhibitors, Intellikine (Intellikine Inc.), PI3-delta/gamma inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd.), PI3-

Date reçue/Date received 2024-05-31

delta/gamma inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd.), PI3-gamma inhibitor Evotec (Evotec), PI3-gamma inhibitor, Cellzome (Cellzome AG), PI3-gamma inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd.), PI3K delta/gamma inhibitors, Intellikine-1 (Intellikine Inc.), PI3K delta/gamma inhibitors, Intellikine-1 (Intellikine Inc.), pictilisib (Roche Holdings Inc.), PIK-90 (CAS # 677338-12-4), SC-103980 (Pfizer, New York, NY), SF-1126 (Semafore Pharmaceuticals, Indianapolis, IN), SH-5, SH-6, Tetrahydro Curcumin, TG100-115 (Targegen Inc., San Diego, CA), Triciribine, X-339 (Xcovery, West Palm Beach, FL), XL-499 (Evotech, Hamburg, Germany), pharmaceutically acceptable salts thereof, and combinations thereof.

[0106] In the present invention, the term "toxin" means an antigenic poison or venom of plant or animal origin. An example is diphtheria toxin or portions thereof.

[0107] In the present invention, the term "radionuclide" means a radioactive substance administered to the patient, e.g., intravenously or orally, after which it penetrates via the patient's normal metabolism into the target organ or tissue, where it delivers local radiation for a short time. Examples of radionuclides include, but are not limited to, I-125, At-211, Lu-177, Cu-67, I-131, Sm-153, Re-186, P-32, Re-188, In-114m, and Y-90.

[0108] In the present invention, the term "immunomodulator" means a substance that alters the immune response by augmenting or reducing the ability of the immune system to produce antibodies or sensitized cells that recognize and react with the antigen that initiated their production. Immunomodulators may be recombinant, synthetic, or natural preparations and include cytokines, corticosteroids, cytotoxic agents, thymosin, and immunoglobulins. Some immunomodulators are naturally present in the body, and certain of these are

Date reçue/Date received 2024-05-31

available in pharmacologic preparations. Examples of immunomodulators include, but are not limited to, granulocyte colony-stimulating factor (G-CSF), interferons, imiquimod and cellular membrane fractions from bacteria, IL-2, IL-7, IL-12, CCL3, CCL26, CXCL7, and synthetic cytosine phosphate-guanosine (CpG).

[0109] In the present invention, the term "photoactive therapeutic agent" means compounds and compositions that become active upon exposure to light. Certain examples of photoactive therapeutic agents are disclosed, e.g., in U.S. Patent Application Serial No. 2011/0152230 A1, "Photoactive Metal Nitrosyls For Blood Pressure Regulation And Cancer Therapy."

[0110] In the present invention, the term "radiosensitizing agent" means a compound that makes tumor cells more sensitive to radiation therapy. Examples of radiosensitizing agents include misonidazole, metronidazole, tirapazamine, and trans sodium crocetinate.

[0111] In the present invention, the term "hormone" means a substance released by cells in one part of a body that affects cells in another part of the body. Examples of hormones include, but are not limited to, prostaglandins, leukotrienes, prostacyclin, thromboxane, amylin, antimullerian hormone, adiponectin, adrenocorticotropic hormone, angiotensinogen, angiotensin, vasopressin, atriopeptin, brain natriuretic peptide, calcitonin, cholecystokinin, corticotropin-releasing hormone, encephalin, endothelin, erythropoietin, follicle-stimulating hormone, galanin, gastrin, ghrelin, glucagon, gonadotropin-releasing hormone, growth hormone-releasing hormone, human chorionic gonadotropin, human placental lactogen, growth hormone, inhibin, insulin, somatomedin, leptin, liptropin, luteinizing hormone, melanocyte stimulating hormone, motilin, orexin, oxytocin, pancreatic polypeptide, parathyroid hormone, prolactin, prolactin releasing hormone,

Date reçue/Date received 2024-05-31

relaxin, renin, secretin, somatostain, thrombopoietin, thyroid-stimulating hormone, testosterone, dehydroepiandrosterone, androstenedione, dihydrotestosterone, aldosterone, estradiol, estrone, estriol, cortisol, progesterone, calcitriol, and calcidiol.

[0112] Some compounds interfere with the activity of certain hormones or stop the production of certain hormones. These hormone-interfering compounds include, but are not limited to, tamoxifen (Nolvadex®), anastrozole (Arimidex®), letrozole (Femara®), and fulvestrant (Faslodex®). Such compounds are also within the meaning of hormone in the present invention.

[0113] As used herein, an "anti-angiogenesis" agent means a substance that reduces or inhibits the growth of new blood vessels, such as, e.g., an inhibitor of vascular endothelial growth factor (VEGF) and an inhibitor of endothelial cell migration. Anti-angiogenesis agents include without limitation 2-methoxyestradiol, angiostatin, bevacizumab, cartilage-derived angiogenesis inhibitory factor, endostatin, IFN-α, IL-12, itraconazole, linomide, platelet factor-4, prolactin, SU5416, suramin, tasquinimod, tecogalan, tetrathiomolybdate, thalidomide, thrombospondin, thrombospondin, TNP-470, ziv-aflibercept, pharmaceutically acceptable salts thereof, prodrugs, and combinations thereof.

[0114] In an additional aspect of this embodiment, administration of the first and second anti-cancer agents provides a synergistic effect compared to administration of either anti-cancer agent alone. As used herein, "synergistic" means more than additive. Synergistic effects may be measured by various assays known in the art, including but not limited to those disclosed herein, such as the excess over bliss assay.

[0115] Another embodiment of the present invention is a method of treating or ameliorating the effects of a cancer in a subject in need thereof. This method

Date reçue/Date received 2024-05-31

comprises administering to the subject an effective amount of (i) BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is dabrafenib or a pharmaceutically acceptable salt thereof, to treat or ameliorate the effects of the cancer.

[0116] Suitable and preferred subjects are as disclosed herein. In this embodiment, the methods may be used to treat the cancers disclosed above, including those cancers with the mutational backgrounds identified above. Methods of identifying such mutations are also as set forth above.

[0117] In one aspect of this embodiment, the BVD-523 or a pharmaceutically acceptable salt thereof is administered in the form of a pharmaceutical composition further comprising a pharmaceutically acceptable carrier or diluent.

[0118] In a further aspect of this embodiment, the dabrafenib or a pharmaceutically acceptable salt thereof is administered in the form of a pharmaceutical composition further comprising a pharmaceutically acceptable carrier or diluent.

[0119] In a further aspect of this embodiment, the method further comprises administering at least one additional therapeutic agent, preferably an inhibitor of the PI3K/Akt pathway, as disclosed herein.

[0120] In an additional aspect of this embodiment, administration of the first and second anti-cancer agents provides a synergistic effect compared to administration of either anti-cancer agent alone.

[0121] Another embodiment of the present invention is a method of effecting cancer cell death. This method comprises contacting the cancer cell with an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a

Date reçue/Date received 2024-05-31

pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a type 1 RAF inhibitor or a pharmaceutically acceptable salt thereof.

[0122] Suitable and preferred type 1 RAF inhibitors are as disclosed herein. In this embodiment, effecting cancer cell death may be accomplished in cancer cells having various mutational backgrounds and/or that are characterized as disclosed above. Methods of identifying such mutations are also as set forth above.

[0123] In an aspect of this embodiment, the methods may be carried out in vitro or in vivo, and may be used to effect cancer cell death, by e.g., killing cancer cells, in cells of the types of cancer disclosed herein.

[0124] In another aspect of this embodiment, the cancer cell is a mammalian cancer cell. Preferably, the mammalian cancer cell is obtained from a mammal selected from the group consisting of humans, primates, farm animals, and domestic animals. More preferably, the mammalian cancer cell is a human cancer cell.

[0125] In a further aspect of this embodiment, contacting the cancer cell with the first and second anti-cancer agents provides a synergistic effect compared to contacting the cancer cell with either anti-cancer agent alone.

[0126] In another aspect of this embodiment, the method further comprises contacting the cancer cell with at least one additional therapeutic agent, preferably an inhibitor of the PI3K/Akt pathway, as disclosed herein.

[0127] In a further aspect of this embodiment, contacting the cancer cell with the first and second anti-cancer agents provides a synergistic effect compared to contacting the cancer cell with either anti-cancer agent alone. In this embodiment, "contacting" means bringing BVD-523 and the type 1 RAF inhibitors, and optionally one or more additional therapeutic agents into close proximity to the cancer cells. This may be accomplished using conventional techniques of drug delivery to

Date reçue/Date received 2024-05-31

mammals or in the *in vitro* situation by, *e.g.*, providing BVD-523 and the type 1 RAF inhibitors, and optionally other therapeutic agents to a culture media in which the cancer cells are located.

[0128] A further embodiment of the present invention is a kit for treating or ameliorating the effects of a cancer in a subject in need thereof. This kit comprises an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a type 1 RAF inhibitor or a pharmaceutically acceptable salt thereof, packaged together with instructions for their use.

[0129] The kits may also include suitable storage containers, *e.g.*, ampules, vials, tubes, etc., for each anti-cancer agent of the present invention (which may e.g., may be in the form of pharmaceutical compositions) and other reagents, *e.g.*, buffers, balanced salt solutions, etc., for use in administering the anti-cancer agents to subjects. The anti-cancer agents of the invention and other reagents may be present in the kits in any convenient form, such as, *e.g.*, in a solution or in a powder form. The kits may further include a packaging container, optionally having one or more partitions for housing the pharmaceutical composition and other optional reagents.

[0130] Suitable and preferred subjects and type 1 RAF inhibitors are as disclosed herein. In this embodiment, the kit may be used to treat the cancers disclosed above, including those cancers with the mutational backgrounds identified herein. Methods of identifying such mutations are as set forth above.

[0131] In a further aspect of this embodiment, the kit further comprises at least one additional therapeutic agent, preferably an inhibitor of the PI3K/Akt pathway, as disclosed herein.

Date reçue/Date received 2024-05-31

[0132] In an additional aspect of this embodiment, administration of the first and second anti-cancer agents provides a synergistic effect compared to administration of either anti-cancer agent alone.

[0133] Another embodiment of the present invention is a pharmaceutical composition for treating or ameliorating the effects of a cancer in a subject in need thereof. This pharmaceutical composition comprises a pharmaceutically acceptable diluent or carrier and an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a type 1 RAF inhibitor or a pharmaceutically acceptable salt thereof, wherein administration of the first and second anti-cancer agents provides a synergistic effect compared to administration of either anti-cancer agent alone. This pharmaceutical composition may further comprise a pharmaceutically acceptable diluent or carrier.

[0134] Suitable and preferred subjects and type 1 RAF inhibitors are as disclosed herein. The pharmaceutical compositions of the invention may be used to treat the cancers disclosed above, including those cancers with the mutational backgrounds identified herein. Methods of identifying such mutations are also as set forth above.

[0135] In a further aspect of this embodiment, the pharmaceutical composition further comprises at least one additional therapeutic agent, preferably an inhibitor of the PI3K/Akt pathway, as disclosed herein.

[0136] Another embodiment of the present invention is a method of treating or ameliorating the effects of a cancer in a subject in need thereof. This method comprises administering to the subject an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a

Date reçue/Date received 2024-05-31

second anti-cancer agent, which is a RAF inhibitor selected from the group consisting of AAL881 (Novartis); AB-024 (Ambit Biosciences), ARQ-736 (ArQule), ARQ-761 (ArQule), AZ628 (Axon Medchem BV), BeiGene-283 (BeiGene), BIIB-024 (MLN 2480) (Sunesis & Takeda), b-raf inhibitor (Sareum), BRAF kinase inhibitor (Selexagen Therapeutics), BRAF siRNA 313 (tacaccagcaagctagatgca) and 253 (cctatcgttagagtcttcctg), CTT239065 (Institute of Cancer Research), DP-4978 (Deciphera Pharmaceuticals), HM-95573 (Hanmi), GW-5074 (Sigma Aldrich), ISIS 5132 (Novartis), LErafAON (NeoPharm, Inc.), LBT613 (Novartis), LGX-818 (Novartis), pazopanib (GlaxoSmithKline), PLX5568 (Plexxikon), RAF-265 (Novartis), RAF-365 (Novartis), regorafenib (Bayer Healthcare Pharmaceuticals, Inc.), RO 5126766 (Hoffmann-La Roche), TAK 632 (Takeda), TL-241 (Teligene), XL-281 (Exelixis), pharmaceutically acceptable salts thereof, and combinations thereof, to treat or ameliorate the effects of the cancer. Preferably, the second anti-cancer agent is regorafenib or a pharmaceutically acceptable salt thereof.

[0137] In this embodiment, suitable and preferred subjects are as disclosed herein. In this embodiment, the methods may be used to treat the cancers disclosed above, including those cancers with the mutational backgrounds identified above. Methods of identifying such mutations are also as set forth above.

[0138] In a further aspect of this embodiment, the method further comprises administering at least one additional therapeutic agent, preferably an inhibitor of the PI3K/Akt pathway, as disclosed herein.

[0139] In another aspect of this embodiment, administration of the first and second anti-cancer agents provides a synergistic effect compared to administration of either anti-cancer agent alone.

Date reçue/Date received 2024-05-31

[0140] An additional embodiment of the present invention is a method of effecting cancer cell death. This method comprises contacting the cancer cell with an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a RAF inhibitor selected from the group consisting of AAL881 (Novartis); AB-024 (Ambit Biosciences), ARQ-736 (ArQule), ARQ-761 (ArQule), AZ628 (Axon Medchem BV), BeiGene-283 (BeiGene), BIIB-024 (MLN 2480) (Sunesis & Takeda), b-raf inhibitor (Sareum), BRAF kinase inhibitor (Selexagen Therapeutics), BRAF siRNA 313 (tacaccagcaagctagatgca) and 253 (cctatcgttagagtcttcctg), CTT239065 (Institute of Cancer Research), DP-4978 (Deciphera Pharmaceuticals), HM-95573 (Hanmi), GW-5074 (Sigma Aldrich), ISIS 5132 (Novartis), LErafAON (NeoPharm, Inc.), LBT613 (Novartis), LGX-818 (Novartis), pazopanib (GlaxoSmithKline), PLX5568 (Plexxikon), RAF-265 (Novartis), RAF-365 (Novartis), regorafenib (Bayer Healthcare Pharmaceuticals, Inc.), RO 5126766 (Hoffmann-La Roche), TAK 632 (Takeda), TL-241 (Teligene), XL-281 (Exelixis), pharmaceutically acceptable salts thereof, and combinations thereof. Preferably, the second anti-cancer agent is regorafenib or a pharmaceutically acceptable salt thereof.

[0141] Suitable and preferred cancer cells are as disclosed herein. In this embodiment, effecting cancer cell death may be accomplished in cancer cells having various mutational backgrounds and/or that are characterized as disclosed above. Methods of identifying such mutations are also as set forth above.

[0142] The methods of this embodiment, which may be carried out in vitro or in vivo, may be used to effect cancer cell death, by e.g., killing cancer cells, in cells of the types of cancer disclosed herein.

Date reçue/Date received 2024-05-31

[0143] In one aspect of this embodiment, the cancer cell is a mammalian cancer cell. Preferably, the mammalian cancer cell is obtained from a mammal selected from the group consisting of humans, primates, farm animals, and domestic animals. More preferably, the mammalian cancer cell is a human cancer cell.

[0144] In another aspect of this embodiment, the method further comprises administering at least one additional therapeutic agent, preferably an inhibitor of the PI3K/Akt pathway, as disclosed herein.

[0145] In a further aspect of this embodiment, contacting the cancer cell with the first and second anti-cancer agents provides a synergistic effect compared to contacting the cancer cell with either anti-cancer agent alone.

[0146] In this embodiment, "contacting" means bringing BVD-523 and RAF inhibitors, and optionally one or more additional therapeutic agents into close proximity to the cancer cells. This may be accomplished using conventional techniques of drug delivery to mammals or in the *in vitro* situation by, *e.g.*, providing BVD-523 and RAF inhibitors, and optionally other therapeutic agents to a culture media in which the cancer cells are located.

[0147] A further embodiment of the present invention is a kit for treating or ameliorating the effects of a cancer in a subject in need thereof. This kit comprises an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a RAF inhibitor selected from the group consisting of AAL881 (Novartis); AB-024 (Ambit Biosciences), ARQ-736 (ArQule), ARQ-761 (ArQule), AZ628 (Axon Medchem BV), BeiGene-283 (BeiGene), BIIB-024 (MLN 2480) (Sunesis & Takeda), b-raf inhibitor (Sareum), BRAF kinase inhibitor (Selexagen Therapeutics), BRAF siRNA 313 (tacaccagcaagctagatgca) and 253 (cctatcgttagagtcttcctg), CTT239065

Date reçue/Date received 2024-05-31

(Institute of Cancer Research), DP-4978 (Deciphera Pharmaceuticals), HM-95573 (Hanmi), GW-5074 (Sigma Aldrich), ISIS 5132 (Novartis), LErafAON (NeoPharm, Inc.), LBT613 (Novartis), LGX-818 (Novartis), pazopanib (GlaxoSmithKline), PLX5568 (Plexxikon), RAF-265 (Novartis), RAF-365 (Novartis), regorafenib (Bayer Healthcare Pharmaceuticals, Inc.), RO 5126766 (Hoffmann-La Roche), TAK 632 (Takeda), TL-241 (Teligene), XL-281 (Exelixis), pharmaceutically acceptable salts thereof, and combinations thereof, packaged together with instructions for their use. Preferably, the second anti-cancer agent is regorafenib or a pharmaceutically acceptable salt thereof.

[0148] In this embodiment, suitable and preferred subjects are as disclosed herein. In this embodiment, the kit may be used to treat the cancers disclosed above, including those cancers with the mutational backgrounds identified herein. Methods of identifying such mutations are as set forth above.

[0149] In a further aspect of this embodiment, the kit further comprises at least one additional therapeutic agent, preferably an inhibitor of the PI3K/Akt pathway, as disclosed herein.

[0150] In another aspect of this embodiment, administration of the first and second anti-cancer agents provides a synergistic effect compared to administration of either anti-cancer agent alone.

[0151] Another embodiment of the present invention is a pharmaceutical composition for treating or ameliorating the effects of a cancer in a subject in need thereof. This pharmaceutical composition comprises a pharmaceutically acceptable diluent or carrier and an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is a RAF inhibitor selected from the group consisting of AAL881

Date reçue/Date received 2024-05-31

(Novartis); AB-024 (Ambit Biosciences), ARQ-736 (ArQule), ARQ-761 (ArQule), AZ628 (Axon Medchem BV), BeiGene-283 (BeiGene), BIIB-024 (MLN 2480) (Sunesis & Takeda), b-raf inhibitor (Sareum), BRAF kinase inhibitor (Selexagen Therapeutics), BRAF siRNA 313 (tacaccagcaagctagatgca) and 253 (cctatcgttagagtcttcctg), CTT239065 (Institute of Cancer Research), DP-4978 (Deciphera Pharmaceuticals), HM-95573 (Hanmi), GW-5074 (Sigma Aldrich), ISIS 5132 (Novartis), LErafAON (NeoPharm, Inc.), LBT613 (Novartis), LGX-818 (Novartis), pazopanib (GlaxoSmithKline), PLX5568 (Plexxikon), RAF-265 (Novartis), RAF-365 (Novartis), regorafenib (Bayer Healthcare Pharmaceuticals, Inc.), RO 5126766 (Hoffmann-La Roche), TAK 632 (Takeda), TL-241 (Teligene), XL-281 (Exelixis), pharmaceutically acceptable salts thereof, and combinations thereof, wherein administration of the first and second anti-cancer agents provides a synergistic effect compared to administration of either anti-cancer agent alone.

[0152] In this embodiment, suitable and preferred subjects are as disclosed herein. The pharmaceutical compositions of the invention may be used to treat the cancers disclosed above, including those cancers with the mutational backgrounds identified herein. Methods of identifying such mutations are also as set forth above.

[0153] In a further aspect of this embodiment, the pharmaceutical composition further comprises at least one additional therapeutic agent, preferably an inhibitor of the PI3K/Akt pathway, as disclosed herein.

[0154] The pharmaceutical compositions according to the present invention may be in a unit dosage form comprising both anti-cancer agents. In another aspect of this embodiment, the first anti-cancer agent is in a first unit dosage form and the second anti-cancer agent is in a second unit dosage form, separate from the first.

Date reçue/Date received 2024-05-31

[0155] The first and second anti-cancer agents may be co-administered to the subject, either simultaneously or at different times, as deemed most appropriate by a physician. If the first and second anti-cancer agents are administered at different times, for example, by serial administration, the first anti-cancer agent may be administered to the subject before the second anti-cancer agent. Alternatively, the second anti-cancer agent may be administered to the subject before the first anti-cancer agent.

[0156] In the present invention, an "effective amount" or a “therapeutically effective amount” of an anti-cancer agent of the invention including pharmaceutical compositions containing same that are disclosed herein is an amount of such agent or composition that is sufficient to effect beneficial or desired results as described herein when administered to a subject. Effective dosage forms, modes of administration, and dosage amounts may be determined empirically, and making such determinations is within the skill of the art. It is understood by those skilled in the art that the dosage amount will vary with the route of administration, the rate of excretion, the duration of the treatment, the identity of any other drugs being administered, the age, size, and species of mammal, *e.g.*, human patient, and like factors well known in the arts of medicine and veterinary medicine. In general, a suitable dose of an agent or composition according to the invention will be that amount of the agent or composition, which is the lowest dose effective to produce the desired effect. The effective dose of an agent or composition of the present invention may be administered as two, three, four, five, six or more sub-doses, administered separately at appropriate intervals throughout the day.

[0157] A suitable, non-limiting example of a dosage of BVD-523, a RAF inhibitor or another anti-cancer agent disclosed herein is from about 1 mg/kg to

Date reçue/Date received 2024-05-31

about 2400 mg/kg per day, such as from about 1 mg/kg to about 1200 mg/kg per day, 75 mg/kg per day to about 300 mg/kg per day, including from about 1 mg/kg to about 100 mg/kg per day. Other representative dosages of such agents include about 1 mg/kg, 5 mg/kg, 10 mg/kg, 15 mg/kg, 20 mg/kg, 25 mg/kg, 30 mg/kg, 35 mg/kg, 40 mg/kg, 45 mg/kg, 50 mg/kg, 60 mg/kg, 70 mg/kg, 75 mg/kg, 80 mg/kg, 90 mg/kg, 100 mg/kg, 125 mg/kg, 150 mg/kg, 175 mg/kg, 200 mg/kg, 250 mg/kg, 300 mg/kg, 400 mg/kg, 500 mg/kg, 600 mg/kg, 700 mg/kg, 800 mg/kg, 900 mg/kg, 1000 mg/kg, 1100 mg/kg, 1200 mg/kg, 1300 mg/kg, 1400 mg/kg, 1500 mg/kg, 1600 mg/kg, 1700 mg/kg, 1800 mg/kg, 1900 mg/kg, 2000 mg/kg, 2100 mg/kg, 2200 mg/kg, and 2300 mg/kg per day. The effective dose of BVD-523, RAF inhibitors or other anti-cancer agents disclosed herein may be administered as two, three, four, five, six or more sub-doses, administered separately at appropriate intervals throughout the day.

[0158] The BVD-523, RAF inhibitors or other anti-cancer agents or pharmaceutical compositions containing same of the present invention may be administered in any desired and effective manner: for oral ingestion, or as an ointment or drop for local administration to the eyes, or for parenteral or other administration in any appropriate manner such as intraperitoneal, subcutaneous, topical, intradermal, inhalation, intrapulmonary, rectal, vaginal, sublingual, intramuscular, intravenous, intraarterial, intrathecal, or intralymphatic. Further, the BVD-523, RAF inhibitors or other anti-cancer agents or pharmaceutical compositions containing same of the present invention may be administered in conjunction with other treatments. The BVD-523, RAF inhibitors or other anti-cancer agents or pharmaceutical compositions containing the same may be encapsulated or otherwise protected against gastric or other secretions, if desired.

Date reçue/Date received 2024-05-31

[0159] The pharmaceutical compositions of the invention comprise one or more active ingredients, e.g. anti-cancer agents, in admixture with one or more pharmaceutically-acceptable diluents or carriers and, optionally, one or more other compounds, drugs, ingredients and/or materials. Regardless of the route of administration selected, the agents/compounds of the present invention are formulated into pharmaceutically-acceptable dosage forms by conventional methods known to those of skill in the art. See, *e.g.*, Remington, The Science and Practice of Pharmacy (21st Edition, Lippincott Williams and Wilkins, Philadelphia, PA.).

[0160] Pharmaceutically acceptable diluents or carriers are well known in the art (see, *e.g.*, Remington, The Science and Practice of Pharmacy (21st Edition, Lippincott Williams and Wilkins, Philadelphia, PA.) and The National Formulary (American Pharmaceutical Association, Washington, D.C.)) and include sugars (*e.g.*, lactose, sucrose, mannitol, and sorbitol), starches, cellulose preparations, calcium phosphates (*e.g.*, dicalcium phosphate, tricalcium phosphate and calcium hydrogen phosphate), sodium citrate, water, aqueous solutions (*e.g.*, saline, sodium chloride injection, Ringer's injection, dextrose injection, dextrose and sodium chloride injection, lactated Ringer's injection), alcohols (*e.g.*, ethyl alcohol, propyl alcohol, and benzyl alcohol), polyols (*e.g.*, glycerol, propylene glycol, and polyethylene glycol), organic esters (*e.g.*, ethyl oleate and tryglycerides), biodegradable polymers (*e.g.*, polylactide-polyglycolide, poly(orthoesters), and poly(anhydrides)), elastomeric matrices, liposomes, microspheres, oils (*e.g.*, corn, germ, olive, castor, sesame, cottonseed, and groundnut), cocoa butter, waxes (*e.g.*, suppository waxes), paraffins, silicones, talc, silicylate, etc. Each pharmaceutically acceptable diluent or carrier used in a pharmaceutical composition of the invention must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not

Date reçue/Date received 2024-05-31

injurious to the subject. Diluents or carriers suitable for a selected dosage form and intended route of administration are well known in the art, and acceptable diluents or carriers for a chosen dosage form and method of administration can be determined using ordinary skill in the art.

[0161] The pharmaceutical compositions of the invention may, optionally, contain additional ingredients and/or materials commonly used in pharmaceutical compositions. These ingredients and materials are well known in the art and include (1) fillers or extenders, such as starches, lactose, sucrose, glucose, mannitol, and silicic acid; (2) binders, such as carboxymethylcellulose, alginates, gelatin, polyvinyl pyrrolidone, hydroxypropylmethyl cellulose, sucrose and acacia; (3) humectants, such as glycerol; (4) disintegrating agents, such as agar-agar, calcium carbonate, potato or tapioca starch, alginic acid, certain silicates, sodium starch glycolate, cross-linked sodium carboxymethyl cellulose and sodium carbonate; (5) solution retarding agents, such as paraffin; (6) absorption accelerators, such as quaternary ammonium compounds; (7) wetting agents, such as cetyl alcohol and glycerol monostearate; (8) absorbents, such as kaolin and bentonite clay; (9) lubricants, such as talc, calcium stearate, magnesium stearate, solid polyethylene glycols, and sodium lauryl sulfate; (10) suspending agents, such as ethoxylated isostearyl alcohols, polyoxyethylene sorbitol and sorbitan esters, microcrystalline cellulose, aluminum metahydroxide, bentonite, agar-agar and tragacanth; (11) buffering agents; (12) excipients, such as lactose, milk sugars, polyethylene glycols, animal and vegetable fats, oils, waxes, paraffins, cocoa butter, starches, tragacanth, cellulose derivatives, polyethylene glycol, silicones, bentonites, silicic acid, talc, salicylate, zinc oxide, aluminum hydroxide, calcium silicates, and polyamide powder; (13) inert diluents, such as water or other solvents; (14) preservatives; (15) surface-

Date reçue/Date received 2024-05-31

active agents; (16) dispersing agents; (17) control-release or absorption-delaying agents, such as hydroxypropylmethyl cellulose, other polymer matrices, biodegradable polymers, liposomes, microspheres, aluminum monostearate, gelatin, and waxes; (18) opacifying agents; (19) adjuvants; (20) wetting agents; (21) emulsifying and suspending agents; (22), solubilizing agents and emulsifiers, such as ethyl alcohol, isopropyl alcohol, ethyl carbonate, ethyl acetate, benzyl alcohol, benzyl benzoate, propylene glycol, 1,3-butylene glycol, oils (in particular, cottonseed, groundnut, corn, germ, olive, castor and sesame oils), glycerol, tetrahydrofuryl alcohol, polyethylene glycols and fatty acid esters of sorbitan; (23) propellants, such as chlorofluorohydrocarbons and volatile unsubstituted hydrocarbons, such as butane and propane; (24) antioxidants; (25) agents which render the formulation isotonic with the blood of the intended recipient, such as sugars and sodium chloride; (26) thickening agents; (27) coating materials, such as lecithin; and (28) sweetening, flavoring, coloring, perfuming and preservative agents. Each such ingredient or material must be "acceptable" in the sense of being compatible with the other ingredients of the formulation and not injurious to the subject. Ingredients and materials suitable for a selected dosage form and intended route of administration are well known in the art, and acceptable ingredients and materials for a chosen dosage form and method of administration may be determined using ordinary skill in the art.

[0162] The pharmaceutical compositions of the present invention suitable for oral administration may be in the form of capsules, cachets, pills, tablets, powders, granules, a solution or a suspension in an aqueous or non-aqueous liquid, an oil-in-water or water-in-oil liquid emulsion, an elixir or syrup, a pastille, a bolus, an electuary or a paste. These formulations may be prepared by methods known in the

Date reçue/Date received 2024-05-31

art, *e.g.*, by means of conventional pan-coating, mixing, granulation or lyophilization processes.

[0163] Solid dosage forms for oral administration (capsules, tablets, pills, dragees, powders, granules and the like) may be prepared, *e.g.*, by mixing the active ingredient(s) with one or more pharmaceutically-acceptable diluents or carriers and, optionally, one or more fillers, extenders, binders, humectants, disintegrating agents, solution retarding agents, absorption accelerators, wetting agents, absorbents, lubricants, and/or coloring agents. Solid compositions of a similar type may be employed as fillers in soft and hard-filled gelatin capsules using a suitable excipient. A tablet may be made by compression or molding, optionally with one or more accessory ingredients. Compressed tablets may be prepared using a suitable binder, lubricant, inert diluent, preservative, disintegrant, surface-active or dispersing agent. Molded tablets may be made by molding in a suitable machine. The tablets, and other solid dosage forms, such as dragees, capsules, pills and granules, may optionally be scored or prepared with coatings and shells, such as enteric coatings and other coatings well known in the pharmaceutical-formulating art. They may also be formulated so as to provide slow or controlled release of the active ingredient therein. They may be sterilized by, for example, filtration through a bacteria-retaining filter. These compositions may also optionally contain opacifying agents and may be of a composition such that they release the active ingredient only, or preferentially, in a certain portion of the gastrointestinal tract, optionally, in a delayed manner. The active ingredient can also be in microencapsulated form.

[0164] Liquid dosage forms for oral administration include pharmaceutically-acceptable emulsions, microemulsions, solutions, suspensions, syrups and elixirs. The liquid dosage forms may contain suitable inert diluents commonly used in the

Date reçue/Date received 2024-05-31

art. Besides inert diluents, the oral compositions may also include adjuvants, such as wetting agents, emulsifying and suspending agents, sweetening, flavoring, coloring, perfuming and preservative agents. Suspensions may contain suspending agents.

[0165] The pharmaceutical compositions of the present invention for rectal or vaginal administration may be presented as a suppository, which may be prepared by mixing one or more active ingredient(s) with one or more suitable nonirritating diluents or carriers which are solid at room temperature, but liquid at body temperature and, therefore, will melt in the rectum or vaginal cavity and release the active compound. The pharmaceutical compositions of the present invention which are suitable for vaginal administration also include pessaries, tampons, creams, gels, pastes, foams or spray formulations containing such pharmaceutically-acceptable diluents or carriers as are known in the art to be appropriate.

[0166] Dosage forms for the topical or transdermal administration include powders, sprays, ointments, pastes, creams, lotions, gels, solutions, patches, drops and inhalants. The active agent(s)/compound(s) may be mixed under sterile conditions with a suitable pharmaceutically-acceptable diluent or carrier. The ointments, pastes, creams and gels may contain excipients. Powders and sprays may contain excipients and propellants.

[0167] The pharmaceutical compositions of the present invention suitable for parenteral administrations may comprise one or more agent(s)/compound(s) in combination with one or more pharmaceutically-acceptable sterile isotonic aqueous or non-aqueous solutions, dispersions, suspensions or emulsions, or sterile powders which may be reconstituted into sterile injectable solutions or dispersions just prior to use, which may contain suitable antioxidants, buffers, solutes which render the formulation isotonic with the blood of the intended recipient, or suspending or

Date reçue/Date received 2024-05-31

thickening agents. Proper fluidity can be maintained, for example, by the use of coating materials, by the maintenance of the required particle size in the case of dispersions, and by the use of surfactants. These pharmaceutical compositions may also contain suitable adjuvants, such as wetting agents, emulsifying agents and dispersing agents. It may also be desirable to include isotonic agents. In addition, prolonged absorption of the injectable pharmaceutical form may be brought about by the inclusion of agents which delay absorption.

[0168] In some cases, in order to prolong the effect of a drug (*e.g.*, pharmaceutical formulation), it is desirable to slow its absorption from subcutaneous or intramuscular injection. This may be accomplished by the use of a liquid suspension of crystalline or amorphous material having poor water solubility.

[0169] The rate of absorption of the active agent/drug then depends upon its rate of dissolution which, in turn, may depend upon crystal size and crystalline form. Alternatively, delayed absorption of a parenterally-administered agent/drug may be accomplished by dissolving or suspending the active agent/drug in an oil vehicle. Injectable depot forms may be made by forming microencapsule matrices of the active ingredient in biodegradable polymers. Depending on the ratio of the active ingredient to polymer, and the nature of the particular polymer employed, the rate of active ingredient release can be controlled. Depot injectable formulations are also prepared by entrapping the drug in liposomes or microemulsions which are compatible with body tissue. The injectable materials can be sterilized for example, by filtration through a bacterial-retaining filter.

[0170] The formulations may be presented in unit-dose or multi-dose sealed containers, for example, ampules and vials, and may be stored in a lyophilized condition requiring only the addition of the sterile liquid diluent or carrier, for example

Date reçue/Date received 2024-05-31

water for injection, immediately prior to use. Extemporaneous injection solutions and suspensions may be prepared from sterile powders, granules and tablets of the type described above.

[0171] The present invention provides combinations shown to enhance the effects of ERK inhibitors. Herein, applicants have also shown that the combination of different ERK inhibitors is likewise synergistic. Therefore, it is contemplated that the effects of the combinations described herein can be further improved by the use of one or more additional ERK inhibitors. Accordingly, some embodiments of the present invention include one or more additional ERK inhibitors.

[0172] The following examples are provided to further illustrate the methods of the present invention. These examples are illustrative only and are not intended to limit the scope of the invention in any way.

EXAMPLES

Example 1

MATERIALS AND METHODS

[0173] Cancer cell lines were maintained in cell culture under standard media and serum conditions. For dose escalation studies, A375 cells were split, grown to about 40-60% confluence, and then treated with the initial dose of the specified drug. Table 4 shows a summary of drug treatments that were escalated.

Date reçue/Date received 2024-05-31

Table 4 - Summary of Treatments Being Escalated

Treatment	Inhibitor
1	Trametinib (MEKi)
2	Dabrafenib (BRAFi)
3	BVD-523 (ERKi)
4	Dabrafenib (BRAFi) + Trametinib (MEKi)
5	Dabrafenib (BRAFi) + BVD-523 (ERKi)
6	Trametinib (MEKi) + BVD-523 (ERKi)

[0174] Single agent dose escalations were performed based on Little *et al.*, 2011 and is outlined in FIG. 25. Cells were then allowed to grow until 70-90% confluence and split. Split ratios were kept as "normal" as possible and reasonably consistent between treatments (*e.g.* a minimum of 50% of the normal split ratio of the parentals). Medium was refreshed every 3-4 days. When cells again reached about 40-60% confluence, the dose was escalated. In the event that the 40-60% window was missed, the cells were split again and dosed once they reached 40-60% confluence. Again, medium was refreshed every 3-4 days. The process was repeated as required (FIG. 25).

[0175] For single agent treatments, starting concentrations and dose increases were conducted by starting with the approximate IC_{50}, escalating in small increments or, gently, for the initial 4-5 doses, doubling the dose, increasing by the same increment for the next 4 doses, then moving to 1.5-fold increases in concentration for subsequent doses.

[0176] For combination treatments, starting concentrations and dose increases were conducted by starting with half of the approximate IC_{50} of each compound (combination assay suggests this will result in about 40-70% inhibition

Date reçue/Date received 2024-05-31

range), escalating as per single agents (i.e. doing an initial doubling and then increasing by the same increment for the next 4 doses, then moving to 1.5-fold increases in concentration). Table 5 shows the projected dose increases using these schemes.

Table 5 – Projected Dose Increases – Month 1

				Dab/Tram		Dab/523		Tram/523	
Dose	**Tram (nM)**	**Dab (nM)**	**BVD-523 (μM)**	**Dab (nM)**	**Tram (nM)**	**Dab (nM)**	**523 (μM)**	**Tram (nM)**	**523 (μM)**
1	1	5	0.16	2.5	0.5	2.5	0.08	0.5	0.08
2	2	10	0.32	5	1	5	0.16	1	0.16
3	3	15	0.48	7.5	1.5	7.5	0.24	1.5	0.24
4	4	20	0.64	10	2	10	0.32	2	0.32
5	5	25	0.80	12.5	2.5	12.5	0.40	2.5	0.40
6	8	38	1.2	19	4	19	0.6	4	0.6
7	11	56	1.8	28	6	28	0.9	6	0.9
8	17	84	2.7	42	8	42	1.4	8	1.4
9	25	127	4.1	63	13	63	2.0	13	2.0
10	38	190	6.1	95	19	95	3.0	19	3.0
11	57	285	9.1	142	28	142	4.6	28	4.6
12	85	427	13.7	214	43	214	6.8	43	6.8
13	128	641	20.5	320	64	320	10.3	64	10.3
14	192	961	30.8	481	96	481	15.4	96	15.4
15	288	1442	46.1	721	144	721	23.1	144	23.1
16	432	2162	69.2	1081	216	1081	34.6	216	34.6
17	649	3244	103.8	1622	324	1622	51.9	324	51.9
18	973	4865	155.7	2433	487	2433	77.8	487	77.8
19	1460	7298	233.5	3649	730	3649	116.8	730	116.8
20	2189	10947	350.3	5474	1095	5474	175.2	1095	175.2

[0177] Clonal resistant cell populations were derived from resistant cell pools by limiting dilution.

[0178] Proliferation assays were used to track changes in sensitivity to the escalated agent(s) at appropriate time intervals (*e.g.* each month, although the timing is dependent on adequate cell numbers being available). For proliferation

Date reçue/Date received 2024-05-31

assays, cells were seeded in 96-well plates at 3000 cells per well in drug-free DMEM medium containing 10% FBS and allowed to adhere overnight prior to addition of compound or vehicle control. Compounds were prepared from DMSO stocks to give a final concentration range as shown in FIGS. 2A-H. The final DMSO concentration was constant at 0.1%. Test compounds were incubated with the cells for 96 hours at 37°C and 5% CO_2 in a humidified atmosphere. Alamar Blue 10% (v/v) was then added and incubated for 4 hours and fluorescent product was detected using a BMG FLUOstar plate reader. The average media only background value was deducted and the data analyzed using a 4-parameter logistic equation in GraphPad Prism. Paclitaxel was used as a positive control.

[0179] Proliferation assays for month 1 were initiated at day 28 using cells growing in the concentrations of each agent indicated in Table 6.

Table 6 - Initial Concentrations of Drugs Used in Proliferation Assays – Month 1

Line	Dab	Tram	BVD-523
Parental	-	-	-
Tram	-	2 nM	-
Dab	15 nM	-	-
BVD-523	-	-	0.48 μM
Tram + Dab	5 nM	1 nM	-
Dab + BVD-523	7.5 nM	-	0.24 μM
Tram + BVD-523	-	1 nM	0.16 μM

[0180] Proliferation assays for month 2 were initiated at day 56 using cells growing in the concentrations of each agent indicated in Table 7.

Date reçue/Date received 2024-05-31

Table 7 - Initial Concentrations of Drugs Used in Proliferation Assays - Month 2

Line	Dab	Tram	BVD-523
Parental	-	-	-
Tram	-	8 nM	-
Dab	127 nM	-	-
BVD-523	-	-	0.8 μM
Tram + Dab	10 nM	2 nM	-
Dab + BVD-523	12.5 nM	-	0.4 μM
Tram + BVD-523	-	2 nM	0.32 μM

[0181] At the end of the 3 month escalation period, cultures were maintained at the top concentration for 2 weeks prior to the final round of proliferation assays and potential single cell cloning. As the proliferation assays/single cell cloning required actively proliferating cells, for treatments where cells were proliferating very slowly at the top concentration or that were only recently escalated, a backup culture was also maintained at a lower concentration (Table 8). For the BVD-523 treatment, where cells appeared to have almost completely stopped growing and looked particularly fragile at the top concentration (1.8μM), cultures were maintained at a lower concentration for the 2 week period.

Date reçue/Date received 2024-05-31

Table 8 - Details of Treatments Being Cultured at a Fixed Concentration for 2 Weeks

Treatment	Inhibitor	Culture 1	Backup Culture
1	Tram	160 nM	80 nM
2	Dab	3.2 μM	-
3	BVD-523	1.2 μM	0.8 μM
4	Dab + Tram	D: 160 nM T: 30 nM	D: 80 nM T: 16 nM
5	Dab + BVD-523	D: 42 nM 523: 1.4 μM	D: 28 nM 523: 0.9 μM
6	Tram + BVD-523	T: 4 nM 523: 0.6 μM	T: 2.5 nM 523: 0.4 μM

[0182] Proliferation assays for month 3 used cells growing in the concentrations of each agent indicated in Table 9.

Table 9 - Initial Concentrations of Drugs Used in Proliferation Assays - Month 3

Line	Dab	Tram	BVD-523
Parental	-	-	-
Tram	-	160 nM	-
Dab	3.2 μM	-	-
BVD-523	-	-	1.2 μM
Tram + Dab	80 nM	16 nM	-
Dab + BVD-523	28 nM	-	0.9 μM
Tram + BVD-523	-	2.5 nM	0.4 μM

[0183] For combination studies, A375 cells (ATCC) were seeded into triplicate 96-well plates at a cell density of 3000 cells/well in DMEM plus 10% FBS and allowed to adhere overnight prior to addition of test compound or vehicle control. Combinations were tested using a 10x8 dose matrix with a final DMSO concentration of 0.2%. A 96 hour assay incubation period followed, with subsequent addition of Alamar Blue 10% (v/v) and 4 hours incubation prior to reading on a fluorescent plate

Date reçue/Date received 2024-05-31

reader. After reading Alamar Blue, the medium/Alamar Blue mix was flicked off and 100µl of CellTiter-Glo/PBS (1:1) added and the plates processed as per the manufacturer's instructions (Promega). Media only background values were subtracted before the data was analysed. The Bliss additivity model was then applied.

[0184] In brief, predicted fractional inhibition values for combined inhibition were calculated using the equation C_{bliss} =A + B – (A x B) where A and B are the fractional inhibitions obtained by drug A alone or drug B alone at specific concentrations. C_{bliss} is the fractional inhibition that would be expected if the combination of the two drugs were exactly additive. C_{bliss} values are subtracted from the experimentally observed fractional inhibition values to give an 'excess over Bliss' value. Excess over Bliss values greater than 0 indicate synergy, whereas values less than 0 indicate antagonism. Excess over Bliss values are plotted as heat maps ± SD.

[0185] The single and combination data are also presented as dose-response curves generated in GraphPad Prism (plotted using % viability relative to DMSO only treated controls).

[0186] For focused combination studies, the Alamar Blue viability assays were performed as described above for combination studies. Additionally, Caspase-Glo 3/7 assays were performed. In brief, HCT116 cells were seeded in triplicate in white 96-well plates at a cell density of 5000 cells/well in McCoy's 5A plus 10% FBS. A375 cells were seeded at a density of 5000 cells/well in DMEM plus 10% FBS. Cells were allowed to adhere overnight prior to addition of the indicated amount of test compound or vehicle control. The final concentration of DMSO was 0.2%, and 800 nM staurosporine was included as a positive control. 24 and 48 hour assay

Date reçue/Date received 2024-05-31

incubation periods were used. Then, Caspase-Glo® 3/7 50% (v/v) was added, plates were mixed for 5 minutes on an orbital shaker and incubated for 1 hour at room temperature prior to reading on a luminescent plate reader. Media only background values were subtracted before the data was analysed.

Example 2

Dose Escalation and Proliferation Assays – Month 1

Dose Escalation Progress – Month 1

[0187] A375 cells were dose escalated using BVD-523, dabrafenib, and trametinib either as single agents or in combination. Doses were increased in small increments during the first month. Other than a marked reduction in growth rate, cells generally tolerated the escalations well and the doses were planned to be more aggressively escalated using larger increments in month 2. FIGS. 1A-C show month 1 progress for the dose escalation studies.

Proliferation Assay Results – Month 1

[0188] Proliferation assays were performed to assess the response of the escalated cells lines vs. parental cell line, to BVD-523, dabrafenib, and trametinib treatments.

[0189] FIGS. 2A-H show normalized and raw proliferation assay results from month 1 of the studies. Note that differences in max signals in DMSO controls between different treatments (FIGS. 2D-F, 2H) suggest differential growth rates between treatments. These differences may influence the responses of lines to inhibitors in the proliferation assays.

[0190] Table 10 shows IC_{50} data for month 1 of the studies.

Date reçue/Date received 2024-05-31

Table 10 - IC_{50} Data - Month 1

Compound	Cell Line, Relative IC_{50} (nM)						
	Par*	Tram	Dab	BVD-523	Dab/Tram	Dab/523	Tram/523
Dabrafenib	6	29	about 161	8	58	68	11
Trametinib	0.5	2.2	2.5	0.7	3.9	3.1	2.5
BVD-523	189	335	350	268	300	412	263
Paclitaxel	2.2	3.0	3.3	3.4	3.5	3.4	3.4

*Par = Parental cell line

[0191] There were early hints that cells grown in the presence of escalating doses of dabrafenib or trametinib, either as single agents or in combinations, were exhibiting decreased responses to these two agents in proliferation assays.

[0192] In the early stages of month 2, the growth rate of cells in the dabrafenib only treatment notably increased relative to the early stages of month 1. This enabled an increased rate of progression and suggested that resistance was becoming apparent.

Example 3

Dose Escalation and Proliferation Assays – Month 2

Dose Escalation Progress – Month 2

[0193] The second month of studies saw most treatments move into a phase where doses were increased in greater increments (1.5-fold) compared to the initial gentle escalation phase. The single agent escalation of dabrafenib and trametinib was quickest, with cells growing in concentrations equivalent to 100x parental cell IC_{50} (FIGS. 3A,B). The single agent escalation of BVD-523 progressed more slowly compared to dabrafenib and trametinib (FIG. 3C). See FIG. 3D for a comparison of the single agent escalations. BVD-523 escalated cells had a more “fragile”

Date reçue/Date received 2024-05-31

appearance and there was a greater number of floating cells compared to the dabrafenib and trametinib escalated populations.

[0194] The combined agent escalations progressed more slowly than the single agent treatments. The BVD-523/trametinib combination was particularly effective in preventing cells from progressing.

Proliferation Assay Results – Month 2

[0195] Proliferation assays on single agent escalated dabrafenib and trametinib cell populations revealed modest shifts in the dose response curves, suggesting that an additional period of escalation would be beneficial to further enrich for resistant cells. Interestingly, in the proliferations assay, there was evidence to suggest that cells exposed to BVD-523 grew less well upon inhibitor withdrawal, perhaps indicating a level of addiction.

[0196] FIGS. 4A-H show normalized and raw proliferation assay results from month 2 of the studies. Note that differences in max signals in DMSO controls between different treatments (FIGS. 4D-F, 4H) suggest differential growth rates between treatments. These differences may influence the responses of lines to inhibitors in the proliferation assays.

[0197] FIGS. 5A-H show normalized and raw proliferation assay results from month 2 of the studies with a focus on parental and BVD-523 line data only.

[0198] Table 11 shows IC_{50} data for month 2 of the studies. Relative IC_{50}s were determined from 4-parameter curve fits in Prism.

Date reçue/Date received 2024-05-31

Table 11 - IC_{50} Data - Month 2

Compound	Cell Line, Relative IC_{50} (nM)						
	Par*	Tra	Dab	BVD-523	Dab/Tram	Dab/523	Tram/523
Dabrafenib	4.1	6.2	11.5	697	256	218	68
Trametinib	0.4	0.7	1.1	24.3	12.6	6.2	4.6
BVD-523	187	252	284	1706	561	678	435
Paclitaxel	3.7	8.9	1.9	6.5	4.7	4.2	8.9

*Par = Parental cell line

Example 4

Dose Escalation and Proliferation Assays – Month 3

Dose Escalation Progress – Month 3

[0199] FIGS. 6A-C show single and combination agent escalation for month 3 of the studies. FIG. 6D shows a comparison of single agent escalations.

Proliferation Assay Results – Month 3

[0200] FIG. 7 shows an assessment of growth during the proliferation assay in DMSO control wells. FIGS. 8A-D show results from month 3 of the studies. FIGS. 9A-D show results from month 3 of the studies with a focus on single treatment cell lines.

[0201] Table 12 shows IC_{50} data for month 3 of the studies. Relative IC_{50}s were determined from 4-parameter curve fits in Prism. IC_{50} values were not determined for the cell line escalated with trametinib due to a lack of growth during the assay (ND: not done).

Date reçue/Date received 2024-05-31

Table 12 - IC_{50} Data - Month 3

Compound	Cell Line, Relative IC_{50} (nM)						
	Par*	Tram	Dab	BVD-523	Dab/Tram	Dab/523	Tram/523
Dabrafenib	2.1	ND	2.5	18.4	17.9	337	73
Trametinib	0.2	ND	0.4	1.7	2.7	90	11.2
BVD-523	129	ND	198	433	323	1151	296
Paclitaxel	1.9	ND	1.9	6.5	4.7	4.2	8.9

*Par = Parental cell line

Example 5

Combination Study Results

[0202] As expected, A375 cells, which carry a BRAF (V600E) mutation, were sensitive to dabrafenib. Single agent IC_{50} values calculated using Alamar Blue (FIGS. 10, 12, 14) were generally slightly lower for Dabrafenib and BVD-523 compared to those derived using CellTiter-Glo (FIGS. 11, 13, 15). Published IC_{50} values for Dabrafenib and Trametinib in a 72 hour CellTiter-Glo assay were 28 ± 16nM and 5 ± 3nM respectively (Greger *et al.*, 2012; King *et al.*, 2013) – the single agent results reported here are consistent with these values. There was some evidence for a window of synergy in all treatments. Variation between triplicates was low, however, there was some evidence of edge effects that likely explains the apparent enhanced growth observed in some treatments versus the no drug control (*e.g.* particularly apparent in the Trametinib/BVD-523 combination). This makes the interpretation of the Bliss analysis more challenging as in some treatments it may have resulted in the artefactual enhancement in the level of synergy.

[0203] The combination assays were repeated for A375 cells. Additionally, HCT116 cells were used in a follow-up combination assay. The results of these experiments are shown in FIGS. 31-41. Single agent BVD-523, Trametinib and Dabrafenib potencies were consistent with those reported in the previous studies.

Date reçue/Date received 2024-05-31

[0204] HCT116 cells are human colorectal cancer cells with mutations in KRAS. Dabrafenib and Trametinib were antagonist at relevant on-target concentrations. In contrast, Trametinib exhibited synergy with AZ628 over a broad range of combinations, and with higher concentrations of Sorafenib. BVD-523 exhibited windows of synergy with both AZ628 and Sorafenib.

[0205] In A375 cells, trametinib exhibited pockets of synergy at lower concentrations of Dabrafenib and AZ628. BVD-523 exhibited a window of synergy with the lower concentrations of Sorafenib.

Example 6

BVD-523 altered markers of MAPK kinase activity and effector function

[0206] For Western blot studies, HCT116 cells (5 x 10^6) were seeded into 10 cm dishes in McCoy's 5A plus 10% FBS. A375 cells (2.5 x 10^6) were seeded into 10 cm dishes in DMEM plus 10% FBS. Cells were allowed to adhere overnight prior to addition of the indicated amount of test compound (BVD-523) or vehicle control. Cells were treated for either 4 or 24 hours before isolation of whole-cell protein lysates, as specified below. Cells were harvested by trypsinisation, pelleted and snap frozen. Lysates were prepared with RIPA (Radio-Immunoprecipitation Assay) buffer, clarified by centrifugation and quantitated by bicinchoninic acid assay (BCA) assay. 20-50 µg of protein was resolved by SDS-PAGE electrophoresis, blotted onto PVDF membrane and probed using the antibodies detailed in Table 13 (for the 4-hour treatment) and Table 14 (for the 24-hour treatment) below.

Date reçue/Date received 2024-05-31

Table 13 – Antibody Details

Antigen	Size (kDa)	Supplier	Cat No	Dilution	Incubation/ Block Conditions	Secondary
pRSK1/2 pS380	90	Cell Signaling	9335	1:1000	o/n 4°C 5% BSA	anti-rabbit
pRSK1/2 pS380	90	Cell Signaling	11989	1:2000	o/n 4°C 5% BSA	anti-rabbit
pRSK-T359/S363	90	Millipore	04-419	1:40000	o/n 4°C 5% BSA	anti-rabbit
Total RSK	90	Cell Signaling	9333	1:1000	o/n 4°C 5% BSA	anti-rabbit
pErk 1/2	42/44	Cell Signaling	9106S	1:500	o/n 4°C 5% milk	anti-mouse
Total ERK	42/44	Cell Signaling	9102	1:2000	o/n 4°C 5% milk	anti-rabbit
pMEK1/2	45	Cell Signaling	9154	1:1000	o/n 4°C 5% BSA	anti-rabbit
Total MEK	45	Cell Signaling	9126	1:1000	o/n 4°C 5% BSA	anti-rabbit
pS6-pS235	32	Cell Signaling	2211S	1:3000	o/n 4°C 5% milk	anti-rabbit
Total S6	32	Cell Signaling	2217	1:2000	o/n 4°C 5% milk	anti-rabbit
DUSP6	48	Cell Signaling	3058S	1:1000	o/n 4°C 5% BSA	anti-rabbit
Total CRAF	73	BD Bio-sciences	610152	1:2000	o/n 4°C 5% milk	anti-mouse
pCRAF-Ser338	73	Cell Signaling	9427	1:1000	o/n 4°C 5% BSA	anti-rabbit
pRB (Ser780)	105	Cell Signaling	9307	1:2000	o/n 4°C 5% BSA	anti-rabbit
β-Actin	42	Sigma	A5441	1:500,000	o/n 4°C 5% milk	anti-mouse

Date reçue/Date received 2024-05-31

Table 14 – Antibody details

Antigen	Size (kDa)	Supplier	Cat No	Dilution	Incubation/ Block Conditions	Secondary
pRB (Ser780)	105	Cell Signaling	9307	1:2000	o/n 4˚C 5% BSA	anti-rabbit
CCND1	34	Abcam	ab6152	1:500	o/n 4˚C 5% milk	anti-mouse
Bim-EL	23	Millipore	AB17003	1:1000	o/n 4˚C 5% BSA	anti-rabbit
Bim-EL	23	Cell Signaling	2933	1:1000	o/n 4˚C 5% BSA	anti-rabbit
BCL-xL	30	Cell Signaling	2762	1:2000	o/n 4˚C 5% BSA	anti-rabbit
PARP	116/ 89	Cell Signaling	9542	1:1000	o/n 4˚C 5% milk	anti-rabbit
Cleaved Caspase 3	17,19	Cell Signaling	9664X	1:1000	o/n 4˚C 5% milk	anti-rabbit
DUSP6	48	Cell Signaling	3058S	1:1000	o/n 4°C 5% BSA	anti-rabbit
pRSK1/2 pS380	90	Cell Signaling	9335	1:1000	o/n 4°C 5% BSA	anti-rabbit
pRSK1/2 pS380	90	Cell Signaling	11989	1:2000	o/n 4°C 5% BSA	anti-rabbit
pRSK-T359/S363	90	Millipore	04-419	1:40000	o/n 4°C 5% BSA	anti-rabbit
Total RSK	90	Cell Signaling	9333	1:1000	o/n 4°C 5% BSA	anti-rabbit
pErk 1/2	42/44	Cell Signaling	9106S	1:500	o/n 4°C 5% milk	anti-mouse
Total ERK	42/44	Cell Signaling	9102	1:2000	o/n 4°C 5% milk	anti-rabbit
B-Actin	42	Sigma	A5441	1:500,000	o/n 4°C 5% milk	anti-mouse

[0207] FIGS. 16-18 show Western blot analyses of cells treated with BVD-523 at various concentrations for the following: 1) MAPK signaling components in A375 cells after 4 hours; 2) cell cycle and apoptosis signaling in A375 24 hours treatment with various amounts of BVD-523; and 3) MAPK signaling in HCT-116 cells treated for 4 hours. The results show that acute and prolonged treatment with BVD-523 in RAF and RAS mutant cancer cells in-vitro affects both substrate phosphorylation and

Date reçue/Date received 2024-05-31

effector targets of ERK kinases. The concentrations of BVD-523 required to induce these changes is typically in the low micromolar range.

[0208] Changes in several specific activity markers are noteworthy. First, the abundance of slowly migrating isoforms of ERK kinase increase following BVD-523 treatment; modest changes can be observed acutely, and increase following prolonged treatment. While this could indicate an increase in enzymatically active, phosphorylated forms of ERK, it remains noteworthy that multiple proteins subject to both direct and indirect regulation by ERK remain "off" following BVD-523 treatment. First, RSK1/2 proteins exhibit reduced phosphorylation at residues that are strictly dependent on ERK for protein modification (T359/S363). Second, BVD-523 treatment induces complex changes in the MAPK feedback phosphatase, DUSP6: slowly migrating protein isoforms are reduced following acute treatment, while total protein levels are greatly reduced following prolonged BVD-523 treatment. Both of these findings are consistent with reduced activity of ERK kinases, which control DUSP6 function through both post-translational and transcriptional mechanisms. Overall, despite increases in cellular forms of ERK that are typically thought to be active, it appears likely that cellular ERK enzyme activity is fully inhibited following either acute or prolonged treatment with BVD-523.

[0209] Consistent with these observations, effector genes that require MAPK pathway signaling are altered following treatment with BVD-523. The G1/S cell-cycle apparatus is regulated at both post-translational and transcriptional levels by MAPK signaling, and cyclin-D1 protein levels are greatly reduced following prolonged BVD-523 treatment. Similarly, gene expression and protein abundance of apoptosis effectors often require intact MAPK signaling, and total levels of Bim-EL increase following prolonged BVD-523 treatment. As noted above, however, PARP protein

Date reçue/Date received 2024-05-31

cleavage and increased apoptosis were not noted in the A375 cell background; this suggests that additional factors may influence whether changes in BVD-523/ERK-dependent effector signaling are translated into definitive events such as cell death and cell cycle arrest.

[0210] Consistent with the cellular activity of BVD-523, marker analysis suggests that ERK inhibition alters a variety of molecular signaling events in cancer cells, making them susceptible to both decreased cell proliferation and survival.

[0211] In sum, FIGS. 16-18 show that BVD-523 inhibits the MAPK signaling pathway and may be more favorable compared to RAF or MEK inhibition in this setting.

[0212] Finally, properties of BVD-523 may make this a preferred agent for use as an ERK inhibitor, compared to other agents with a similar activity. It is known that kinase inhibitor drugs display unique and specific interactions with their enzyme targets, and that drug efficacy is strongly influenced by both the mode of direct inhibition, as well as susceptibility to adaptive changes that occur following treatment. For example, inhibitors of ABL, KIT, EGFR and ALK kinases are effective only when their cognate target is found in active or inactive configurations. Likewise, certain of these inhibitors are uniquely sensitive to either secondary genetic mutation, or post-translational adaptive changes, of the protein target. Finally, RAF inhibitors show differential potency to RAF kinases present in certain protein complexes and/or subcellular localizations. In summary, as ERK kinases are similarly known to exist in diverse, variable, and complex biochemical states, it appears likely that BVD-523 may interact with and inhibit these targets in a fashion that is distinct and highly preferable to other agents.

Date reçue/Date received 2024-05-31

Example 7

In vivo Assay

Mice

[0213] Female athymic nude mice (Crl:NU(Ncr)-Foxn/^{nu}, Charles River) were nine weeks old with a body weight (BW) range of 17.5 to 26.2 grams on Day 1 of the study. The animals were fed *ad libitum* water (reverse osmosis, 1 ppm Cl), and NIH 31 Modified and Irradiated Lab Diet® consisting of 18.0% crude protein, 5.0% crude fat, and 5.0% crude fiber. The mice were housed on irradiated Enrich-o'cobsTM Laboratory Animal Bedding in static microisolators on a 12-hour light cycle at 20-22°C (68-72°F) and 40-60% humidity. The recommendations of the *Guide for Care and Use of Laboratory Animals* with respect to restraint, husbandry, surgical procedures, feed and fluid regulation, and veterinary care were complied with.

In Vivo Implantation and Tumor Growth

[0214] Tumor xenografts were initiated with A375 human melanomas by serial subcutaneous transplantation in athymic nude mice. On the day of tumor implant, each test mouse received a 1 mm^3 A375 fragment implanted subcutaneously in the right flank, and tumor growth was monitored as the average size approached the target range of 80 to 120 mm^3. Tumors were measured in two dimensions using calipers, and volume was calculated using the formula:

$$\text{Tumor Volume } (mm^3) = \frac{w^2 \times l}{2}$$

where w = width and *l* = length, in mm, of the tumor. Tumor weight may be estimated with the assumption that 1 mg is equivalent to 1 mm^3 of tumor volume.

[0215] Ten days after tumor implantation, designated as Day 1 of the study, the animals were sorted into nine groups (Groups 1-9) each consisting of fifteen

Date reçue/Date received 2024-05-31

mice and one group (Group 10) consisting of ten mice. Individual tumor volumes ranged from 75 to 144 mm^3 and group mean tumor volumes were 110 or 111 mm^3.

Therapeutic Agents

[0216] BVD-523 and dabrafenib were supplied as dry powders and were stored at room temperature protected from light.

[0217] BVD-523 doses were prepared by suspending the required amount of BVD-523 powder in 1% carboxymethyl cellulose in deionized water ("1% CMC"). A 10 mg/mL BVD-523 stock was prepared, and was used to dose the 100 mg/kg BVD-523 group. Aliquots of the stock were diluted with the vehicle to a concentration of 5.0 mg/mL to provide the 50 mg/kg BVD-523 dosage in a dosing volume of 10 mL/kg. The BVD-523 doses were stored at 4°C protected from light for up to one week.

[0218] Dabrafenib dry powder consisted of 84.5% active compound, which was accounted for when preparing doses. Dabrafenib was formulated in 1% CMC at concentrations of 11.834 and 5.917 mg/mL to yield 100 and 50 mg/kg active compound dosages, respectively, in a dosing volume of 10 mL/kg. The dabrafenib doses were stored protected from light at 4°C for up to one week.

[0219] The 1% CMC vehicle ("Vehicle") was used to dose the control group.

[0220] Temozolomide (Temodar®, Schering Corporation, Lot No. 2RSA013) doses were prepared by suspending the contents of the required number of 100 mg Temodar® capsules in deionized water at a concentration of 15 mg/mL, which supplied a 150 mg/kg dosage in a dosing volume of 10 mL/kg. Temozolomide was stored protected from light at 4°C during the 5-day dosing period.

Date reçue/Date received 2024-05-31

Treatment

[0221] On Day 1 of the study, mice were sorted into nine groups (Group 1-9) each consisting of fifteen mice and one group (Group 10) consisting of ten mice, and dosing was initiated according to the treatment plan summarized in Table 15 below. Each dose was given by oral gavage (p.o.) in a dosing volume of 10 mL/kg (0.2 mL per 20 grams of body weight), scaled to the body weight of each individual animal. The vehicle and dabrafenib doses were to be given once daily until study end (qd to end), whereas the BVD-523 doses were to be given twice daily until study end (bid to end). For bid dosing, dosing was initiated in the afternoon on Day 1, so that one dose was given on the first day ("first day 1 dose").

Table 15 - Protocol Design for the A375 *in vivo* Study

		Treatment Regimen			
Group	**n**	**Agent**	**mg/kg**	**Route**	**Schedule**
1	15	Vehicle	-	po	qd to end
2	15	Dabrafenib BVD-523	50 50	po po	qd to end bid to end
3	15	Dabrafenib BVD-523	50 100	po po	qd to end bid to end
4	15	Dabrafenib BVD-523	100 50	po po	qd to end bid to end
5	15	Dabrafenib BVD-523	100 100	po po	qd to end bid to end
6	15	Dabrafenib	50	po	qd to end
7	15	Dabrafenib	100	po	qd to end
8	15	BVD-523	50	po	bid to end
9	15	BVD-523	100	po	bid to end
10	10	Temozolomide	150	po	qd x 5

Vehicle = 1% carboxymethylcellulose (CMC) in DI water
For bid doses, one dose was given in the afternoon on the first day and one dose in the morning on the last day.

Date reçue/Date received 2024-05-31

[0222] Dosing in the combination groups was modified during the study as described below.

Controls

[0223] Group 1 received 1% CMC vehicle, and served as the control group for calculation of %TGD. Group 10 received temozolomide at 150 mg/kg once per day for five days (qd x 5), and served as a reference group.

Monotherapy Treatments

[0224] Groups 6 and 7 received 50 and 100 mg/kg dabrafenib, respectively. Groups 8 and 9 received 50 and 100 mg/kg BVD-523, respectively.

Combination Treatments

[0225] Groups 2 and 3 received the combinations of 50 mg/kg dabrafenib with 50 or 100 mg/kg BVD-523, respectively. Groups 4 and 5 received the combinations of 100 mg/kg dabrafenib with 50 or 100 mg/kg BVD-523, respectively. Due to the striking response to combination treatment, dosing in Groups 2-5 was stopped on Day 20 in order to monitor tumor re-growth. Dosing was to be re-initiated in a group when the mean tumor burden reached 1000 mm^3. By Day 42, the 1000 mm^3 mean tumor burden had not been reached in any of the combination groups. Dosing was re-initiated to permit post-final dose serum and tumor sampling for pharmacokinetic analyses. Beginning on Day 42, Groups 2-5 received dabrafenib given once per day for four days and BVD-523 given twice per day for three days, followed by one BVD-523 dose in the morning on Day 45. The final dosing schedules are shown below in Table 16.

Date reçue/Date received 2024-05-31

Table 16- Response Summary in the A375 in vivo Study

Group	n	Treatment Regimen				Median TTE	T-C	%TGD	Statistical vs G1	Statistical vs G2	Statistical vs G3	Significance vs G4	Significance vs G5	MTV (n) D45	PR	Regessions CR	TFS	Mean BW Nadir	TR	Deaths NTR
		Agent	mg/kg	Route	Schedule															
1	14	Vehicle	-	po	qd to end	9.2	---	---	---	---	---	---	---	---	0	0	0	---	0	1
2	15	Dabrafenib 50 BVD-523 50		po po	qd x 20/21 days off/qd x 4 bid x19/21 days off/bid x 3 then qd x 1	45.0	35.8	389	***	---	---	---	---	0 (10)	3	8	7	---	0	0
3	14	Dabrafenib 50 BVD-523 100		po po	qd x 20/21 days off/qd x 4 bid x19/21 days off/bid x 3 then qd x 1	45.0	35.8	389	***	---	---	---	---	0 (14)	0	14	14	---	0	1
4	15	Dabrafenib 100 BVD-523 50		po po	qd x 20/21 days off/qd x 4 bid x19/21 days off/bid x 3 then qd x 1	45.0	35.8	389	***	---	---	---	---	0 (15)	1	14	14	---	0	0
5	15	Dabrafenib 100 BVD-523 100		po po	qd x 20/21 days off/qd x 4 bid x19/21 days off/bid x 3 then qd x 1	45.0	35.8	389	***	---	---	---	---	0 (15)	0	15	15	---	0	0
6	15	Dabrafenib	50	po	qd to end	16.1	6.9	75	***	***	***	___	___	---	0	0	0	---	0	0
7	15	Dabrafenib	100	po	qd to end	28.5	19.3	210	***	---	---	***	***	282 (2)	1	0	0	---	0	0
8	15	BVD-523	50	po	bid to end	8.6	-0.6	-7	ns	***	---	***	---	0(1)	0	1	1	-0.1% Day 2	0	0
9	15	BVD-523	100	po	bid to end	18.5	9.3	101	***	---	***	---	***	2 (2)	0	2	2	---	0	0
10	10	Temozolomide	150	po	qd x 5	10.5	1.3	14	ns					---	0	0	0	-1.6% Day 5	0	0

n = number of animals in a group not dead from accidental or unknown causes; **Vehicle** = 1% carboxymethylcellulose (CMC) in **DI** water. For bid x 19 and bid to end doses, one dose was given in the afternoon on the first day and one dose in the morning on the last day. The maximum T-C in this study is 35.8 days (389%), compared to Group 1. **Statistical Significance (Logrank test):** *ne* = not evaluated, ns = not significant, * =$P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, compared to group indicated. **MTV (n)** = median tumor volume (imd) for the number of animals on the day of TGD analysis (excludes animals attaining tumor volume endpoint). **PR** = partial regressions; **CR** = total number complete regressions; **TFS** = tumor free survivors, i.e., CRs at end of study**; Mean BW Nadir** = lowest group mean body weight, as % change from Day 1; -– indicates no decrease in mean body weight was observed**; TR** = treatment-related death; **NTR** = non-treatment-related death

Date reçue/Date received 2024-05-31

Endpoint and Tumor Growth Delay (TGD) Analysis

[0226] Tumors were measured using calipers twice per week, and each animal was euthanized when its tumor reached the pre-determined tumor volume endpoint of 2000 mm^3 or on the final day, whichever came first. Animals that exited the study for tumor volume endpoint were documented as euthanized for tumor progression (TP), with the date of euthanasia. The time to endpoint (TTE) for analysis was calculated for each mouse by the following equation:

$$TTE = \frac{\log_0 (\text{endpoint volume}) - b}{m}$$

where TTE is expressed in days, endpoint volume is expressed in mm^3, b is the intercept, and m is the slope of the line obtained by linear regression of a log-transformed tumor growth data set. The data set consists of the first observation that exceeded the endpoint volume used in analysis and the three consecutive observations that immediately preceded the attainment of this endpoint volume. The calculated TTE is usually less than the TP date, the day on which the animal was euthanized for tumor size. Animals with tumors that did not reach the endpoint volume were assigned a TTE value equal to the last day of the study. Any animal classified as having died from NTR (non-treatment-related) causes due to accident (NTRa) or due to unknown etiology (NTRu) were excluded from TTE calculations (and all further analyses). Animals classified as TR (treatment-related) deaths or NTRm (non-treatment-related death due to metastasis) were assigned a TTE value equal to the day of death.

Date reçue/Date received 2024-05-31

[0227] Treatment outcome was evaluated from tumor growth delay (TGD), defined as the increase in the median time to endpoint (TTE) in a treatment group compared to the control group:

$$TGD = T - C,$$

expressed in days, or as a percentage of the median TTE of the control group:

$$\%TGD = \frac{T - C}{C} \times 100$$

where:

T = median TTE for a treatment group, and

C = median TTE for the designated control group.

Criteria for Regression Responses

[0228] Treatment efficacy may be determined from the incidence and magnitude of regression responses observed during the study. Treatment may cause partial regression (PR) or complete regression (CR) of the tumor in an animal. In a PR response, the tumor volume was 50% or less of its Day 1 volume for three consecutive measurements during the course of the study, and equal to or greater than 135 mm^3 for one or more of these three measurements. In a CR response, the tumor volume was less than 135 mm^3 for three consecutive measurements during the course of the study. An animal with a CR response at the termination of a study was additionally classified as a tumor-free survivor (TFS). Animals were monitored for regression responses.

Toxicity

[0229] Animals were weighed daily on Days 1-5, then twice per week until completion of the study. The mice were observed frequently for overt

Date reçue/Date received 2024-05-31

signs of any adverse, treatment-related (TR) side effects, and clinical signs were recorded when observed. Individual body weight loss was monitored as per protocol, and any animal that exceeded the limits for acceptable body weight loss was euthanized. Group mean body weight loss also was monitored as per protocol. Dosing was to be suspended in any group that exceeded the limits for acceptable mean body weight loss. If mean body weight recovered, then dosing was to be resumed in that group, but at a lower dosage or less frequent dosing schedule.

[0230] Acceptable toxicity for the maximum tolerated dose (MTD) was defined as a group mean body-weight loss of less than 20% during the study and not more than 10% treatment-related (TR) deaths. A death was classified as TR if attributable to treatment side effects as evidenced by clinical signs and/or necropsy, or was also classified as TR if due to unknown causes during the dosing period or within 14 days of the last dose. A death was classified as non-treatment-related (NTR) if there was no evidence that death was related to treatment side effects. NTR deaths were further characterized based on cause of death. A death was classified as NTRa if it resulted from an accident or human error. A death was classified as NTRm if necropsy indicated that it may have resulted from tumor dissemination by invasion and/or metastasis. A death was classified as NTRu if the cause of death was unknown and there was no available evidence of death related to treatment side effects, metastasis, accident or human error, although death due to treatment side effects cannot be excluded.

Date reçue/Date received 2024-05-31

Sampling

[0231] When available, five mice per group were euthanized by terminal cardiac puncture under carbon dioxide anesthesia at 3, 6 and 12 hours post final dose, and the full blood volume of each animal was collected. The serum was separated and stored frozen at -80°C until shipment. In addition, the tumors of these mice were harvested and divided into two parts. One part was snap frozen and stored at -80°C. The other part was fixed for 16-24 hours in 10% neutral buffered formalin, and then transferred to 70% ethanol. For groups with mice that had no detectable tumor, the implant site including full skin and muscle thickness was collected from three mice per group.

Statistical and Graphical Analyses

[0232] Prism (GraphPad) for Windows 3.03 was used for graphical representations and statistical analyses.

[0233] The logrank test, which evaluates overall survival experience, was used to analyze the significance of the differences between the TTE values of two groups. Logrank analysis includes the data for all animals in a group except those assessed as NTR deaths. Two-tailed statistical analyses were conducted at significance level $P = 0.05$. The statistical tests were not adjusted for multiple comparisons. Prism summarizes test results as not significant (ns) at $P > 0.05$, significant (symbolized by "*") at $0.01 < P < 0.05$, very significant ("**") at $0.001 < P < 0.01$, and extremely significant ("***") at $P < 0.001$. Because tests of statistical significance do not provide an estimate of the magnitude of the difference between groups, all levels of significance

Date reçue/Date received 2024-05-31

were described as either significant or not significant within the text of this report.

[0234] A scatter plot was constructed to show TTE values for individual mice, by group. Group mean tumor volumes were plotted as a function of time. When an animal exited the study due to tumor size, the final tumor volume recorded for the animal was included with the data used to calculate the mean volume at subsequent time points. Error bars (when present) indicate one standard error of the mean (SEM). Kaplan-Meier plots show the percentage of animals in each group remaining in the study versus time. The Kaplan-Meier plot and logrank test share the same TTE data sets. Percent mean body weight changes from Day 1 were calculated for each group for each day of body weight measurement, and were plotted as a function of time. Tumor growth and body weight plots excluded the data for NTR deaths, and were truncated after 50% of the assessable animals in a group had exited the study.

Results

[0235] Groups in the A375 in vivo study were treated in accordance with the modified protocol as disclosed in Table 15. The experiment was terminated on Day 45. Table 16 presents a summary of the treatment responses for each group. FIG. 26 is a scatter plot showing the individual TTEs for each group. FIG. 27 presents plots of mean tumor growth (FIG. 27A) and Kaplan-Meier survival (FIG. 27B) for each group in the study. FIGS. 28A-D present mean tumor growth plots for the four combinations compared to their respective monotherapies. FIG. 29 presents plots of percent mean body weight changes from Day 1 for each group.

Date reçue/Date received 2024-05-31

Efficacy- Growth of A375 Human Melanomas in Control Mice (Group 1)

[0236] In Group 1, one control mouse was found dead beyond necropsy on Day 4, and the death was assessed as NTRu. The other fourteen control tumors progressed rapidly and uniformly to the 2000 mm^3 endpoint with a median TTE of 9.2 days, establishing a maximum possible TGD of 35.8 days (389%) for the 45-day study (Table 15). The scatter plot shows a cluster of control TTEs (FIG. 26). The mean tumor growth plot for Group 1 illustrated the rapid control tumor growth (FIG. 27A, and FIG. 28A-D).

Efficacy-Response to Dabrafenib as Monotherapy (Groups 6 and 7)

[0237] Groups 6 and 7 received dabrafenib as monotherapy at 50 and 100 mg/kg, respectively, p.o. qd to end. The median TTEs for Groups 6 and 7 were 16.1 and 28.5 days, respectively, corresponding to dose-related TGDs of 6.9 days (75%) and 19.3 days (210%), with a significant survival difference for each compared to controls (Group 1 vs.6 or 7, $P < 0.001$). One PR was recorded in the 100 mg/kg dabrafenib group (Table 16). All Group 6 tumors attained the 2000 mm^3 endpoint tumor volume, whereas 13/15 Group 7 tumors attained the endpoint and two remained on Day 45 with a MTV of 282 mm^3 (Table 16). The mean tumor growth plots for Groups 6 and 7 illustrated the dose-related delays, although tumors in both groups progressed during treatment (FIG. 27A).

Efficacy-Response to BVD-523 as Monotherapy (Groups 8 and 9)

[0238] Groups 8 and 9 received BVD-523 as monotherapy at 50 and 100 mg/kg, respectively, p.o. bid to end. The median TTEs for Groups 8 and 9 were 8.6 and 18.5 days, respectively, which corresponded to no TGD for the 50 mg/kg BVD-523 group and TGD of 9.3 days (101%) for the 100 mg/kg

Date reçue/Date received 2024-05-31

BVD-523 group (Table 16). Logrank analyses detected a significant survival difference only for 100 mg/kg BVD-523 compared to controls (Group 1 vs. 8, $P > 0.05$; Group 1 vs. 9, $P < 0.001$). Group 8 had one CR that remained a TFS on Day 45, while Group 9 had two CRs/TFSs, and all other tumors in these two groups attained the 2000 mm^3 endpoint tumor volume (Table 16). The mean tumor growth plot for the 50 mg/kg BVD-523 group was comparable to that for controls, whereas the 100 mg/kg BVD-523 group showed marginal delay with tumors that progressed during treatment (FIG. 27A).

Efficacy-Response to Treatment with Combinations of Dabrafenib and BVD-523 (Groups 2-5)

[0239] Groups 2 and 3 received 50 mg/kg dabrafenib with 50 or 100 mg/kg BVD-523, respectively, whereas Groups 4 and 5 received 100 mg/kg dabrafenib with 50 or 100 mg/kg BVD-523, respectively. As indicated in Table 16, the combination regimens were modified so that dosing was ended after Day 20 and then re-initiated on Day 42 (Table 16).

[0240] The median TTEs for Groups 2-5 were each 45.0 days, corresponding to the maximum possible TGD for the study (35.8 days, 389%) and a significant overall survival benefit compared to controls (Group 1 vs. 2-5, $P < 0.001$).

[0241] Five tumors in Group 2 attained the 2000 mm^3 endpoint volume, whereas Groups 3-5 had no tumors that grew to the endpoint volume. Group 2 had three PRs and eight CRs, with seven mice that remained TFSs on Day 45 (Table 16). Group 3 had one NTRu death on Day 31, and the other

Date reçue/Date received 2024-05-31

fourteen mice had CRs and remained TFSs at study end. Group 4 had one PR and fourteen CRs that remained TFSs, whereas Group 5 had 100% TFSs.

[0242] Mean tumor burdens were non-detectable in Groups 2-5 by Day 20 when dosing was stopped (FIG. 27A). Mean tumor growth resumed only in the lowest dosage combination group (Group 2), and remained non-detectable through study end in the other three combination groups (FIG. 27AI). The tumor growth plot for each combination group showed noteworthy activity compared to its corresponding monotherapies (FIGS. 28A-D).

Efficacy-Response to Temozolomide Treatment (Group 10)

[0243] The temozolomide reference treatment resulted in a median TTE of 10.5 days, which corresponded to negligible TGD (1.3 days, 14%), with no regressions (Table 16). Logrank analyses detected no significant survival difference for the temozolomide group compared to controls (Group 1 vs. 10, P = 0.052). The mean tumor growth plot for this group showed negligible delay compared to the plot for Group 1 controls (FIG. 27A).

Side Effects

[0244] Table 16 provides a summary of maximum mean BW losses, TR and NTR deaths. FIG. 29 presents plots of percent mean BW changes from Day 1 for each group.

[0245] No TR deaths were recorded in the study, but two NTRu deaths were assessed (Table 16). One NTRu death was recorded in Group 1 on Day 4, and a second NTRu death was recorded in Group 3 on Day 31. The Group 1 animal was found dead beyond necropsy with no prior clinical observations, whereas the Group 3 mouse was thin, hunched and lethargic just prior to death, and necropsy revealed a mass of white nodules on the liver

Date reçue/Date received 2024-05-31

suggesting metastatic disease was a possible cause of death. There were negligible or no mean BW losses among groups in the study (Table 16 and FIG. 29), and no noteworthy signs of treatment-related side effects among the BVD-523 and dabrafenib mono- and combination therapy groups.

Summary

[0246] The *in vivo* study evaluated combinations of BVD-523 with dabrafenib for efficacy in the A375 human melanoma xenograft nude mouse model. BVD-523 was administered orally at 50 or 100 mg/kg on a twice daily schedule and dabrafenib was given orally at 50 or 100 mg/kg on a daily schedule, alone and in combination. Due to the striking response to combination treatment, dosing in the combination groups was stopped on Day 20 to monitor for tumor re-growth, and was reinitiated on Day 42 for sample collection at study end on Day 45.

[0247] A375 control tumors progressed rapidly and uniformly to the tumor volume endpoint. The median TTE for controls was 9.2 days, establishing a maximum possible TGD of 35.8 days (389%) for the 45-day study. A narrow range of control TTEs, which reflected the uniform control tumor growth, permitted the logrank test to detect small differences between control and treated mice. The temozolomide reference treatment resulted in negligible TGD (1.3 days, 14%) and no regressions, consistent with previous results for temozolomide in this tumor model.

[0248] The 50 and 100 mg/kg dabrafenib monotherapies produced dose-related efficacy, with TGDs of 6.9 days (75%) and 19.3 days (210%), respectively, and one PR in the 100 mg/kg dabrafenib group. The 50 mg/kg BVD-523 monotherapy was inactive, producing no TGD and no significant

Date reçue/Date received 2024-05-31

survival difference from controls ($P > 0.05$). The single TFS in this group might have been due to treatment or a spontaneous regression. The 100 mg/kg BVD-523 monotherapy was marginally active, resulting TGD of 9.3 days (101%), a significant survival difference versus controls ($P < 0.001$), and two TFSs that could have been due to treatment or a spontaneous regression.

[0249] Each of the four combinations of dabrafenib with BVD-523 tested in this study was highly active, producing the maximum possible TGD, noteworthy regression responses, and statistically superior overall survival compared to their corresponding monotherapies ($P < 0.001$). The lowest dosage combination group (Group 2) produced a noteworthy 7/15 TFSs. The three higher dosage combinations (Groups 3-5) achieved 43/44 tumor-free survivors by study end, including 15/15 TFSs in the highest dosage combination group (Group 5). It is noteworthy that, given a mean doubling time of less than 3 days for control tumors, no tumor re-growth occurred in 43/44 mice among Groups 3-5 during the dosing holiday from Days 21 to 42, which was a duration of time corresponding to approximately 7 tumor doublings. These results were consistent with curative or near-curative activity.

[0250] In summary, dabrafenib and BVD-523 each produced marginal dose-related efficacy as monotherapies, but remarkable activity in combination. The combinations of dabrafenib with BVD-523 tested in this study produced noteworthy tumor-free survival, and superior efficacy to either agent given alone.

[0251] We show that ERK kinase inhibition, exemplified using BVD-523, is effective in combination with the RAF inhibitor dabrafenib in a model of

Date reçue/Date received 2024-05-31

BRAF mutant melanoma. In cells, combined BVD-523 and dabrafenib treatment induces windows of synergistic inhibition of cell proliferation. When dosed together in a xenograft model, combination treatment causes prominent and durable tumor regression compared to single agent therapy.

[0252] Additionally, when A375 cells are induced to exhibit acquired drug resistance following prolonged exposure to inhibitors of the MAPK cascade, ERK inhibition using BVD-523 shows attractive properties. Within weeks following treatment with dabrafenib or trametinib, A375 cells can be isolated that grow rapidly in concentrations greater 10-fold more than the respective compound growth IC50 inhibitory concentration. After 2 months, cells exposed to BVD-523 alone grow poorly, and can only withstand treatment with less than 10-fold increases in drug exposures beyond the IC50. Cells treated with the combination of BVD-523 and dabrafenib similarly exhibit poor growth, and can only be cultured in modestly increased levels of dabrafenib when in combination.

[0253] Lastly, BVD-523 was tested in a melanoma xenograft model derived from biopsies obtained from a patient that exhibited disease progression following initial response to vemurafenib. Interestingly, this *in vivo* model exhibited acquired cross-resistance, appearing insensitive to both dabrafenib and trametinib. BVD-523 appears effective in the model however, and induced a potent anti-tumor response either alone or in combination with dabrafenib.

[0254] In total, these results suggest combined ERK and RAF inhibitor treatment is effective in the background of BRAF mutant melanoma. BVD-523 has a novel mode of drug action, and possibly exhibits prolonged

Date reçue/Date received 2024-05-31

duration in models that show both intrinsic sensitivity or acquired resistance to BRAF or MEK inhibitors. The combination of RAF and ERK inhibitors for BRAF mutant cancers inhibits an oncogenic pathway at two control points, which in turn appears to create a difficult barrier against subversion and acquired drug resistance.

[0255] These findings indicate that therapy with the combination of ERK and RAF inhibitors may be effective in a variety of cancers, particularly those that harbor oncogenic changes in BRAF, including melanoma, thyroid, lung and colon cancers.

Example 8

Additional Combination Studies

Single Agent Proliferation Assay

[0256] Cells were seeded in 96-well plates at the densities and media conditions indicated in Table 17 and allowed to adhere overnight prior to addition of compound or vehicle control. Compounds were prepared from DMSO stocks to give the desired final concentrations. The final DMSO concentration was constant at 0.1%. Test compounds were incubated with the cells for 72h at 37°C, 5% CO_2 in a humidified atmosphere. CellTiter-Glo® reagent (Promega, Madison, WI) was added according to manufacturer's instructions and luminescence detected using the BMG FLUOstar plate reader (BMG Labtech, Ortenberg, Germany). The average media only background value was deducted and the data analysed using a 4-parameter logistic equation in GraphPad Prism (GraphPad Software, La Jolla, CA).

Combination Proliferation Assay

Date reçue/Date received 2024-05-31

[0257] Cells were seeded in triplicate 96-well plates at the densities and media conditions indicated in Table 17 and allowed to adhere overnight prior to addition of compound or vehicle control. Compounds were prepared from DMSO stocks to give the desired final concentrations. The final DMSO concentration was constant at 0.2%. Combinations were tested using a 10 x 8 dose matrix. Test compounds were incubated with the cells for 72h at 37°C, 5% CO_2 in a humidified atmosphere. CellTiter-Glo® reagent (Promega, Madison, WI) was added according to manufacturer's instructions and luminescence detected using the BMG FLUOstar plate reader (BMG Labtech, Ortenberg, Germany). The average media only background value was deducted and the data analysed.

[0258] For the 10 x 8 combination assays the combination interactions across the dose matrix were determined by the Loewe Additivity and Bliss independence models using Chalice™ Combination Analysis Software (Horizon Discovery Group, Cambridge, MA) as outlined in the user manual (available at chalice.horizondiscovery.com/chalice-portal/documentation/analyzer/home.jsp). Synergy is determined by comparing the experimentally observed level of inhibition at each combination point with the value expected for additivity, which is derived from the single-agent responses along the edges of the matrix. Potential synergistic interactions were identified by displaying the calculated excess inhibition over that predicted as being additive across the dose matrix as a heat map, and by reporting a quantitative 'Synergy Score' based on the Loewe model. The single agent data derived from the combination assay plates were presented as dose-response curves generated in GraphPad Prism (GraphPad Software,

Date reçue/Date received 2024-05-31

La Jolla, CA) (plotted using percentage viability relative to DMSO only treated controls).

Table 17 - Cell Line Seeding Density and Growth Media

Cell Line	Seeding Density (cells/well)	Media
A375	2500	DMEM + 10% FBS
G-361	5000	McCoy's 5A + 10% FBS

Results

[0259] The aim of this study was to assess the effects of combining ERK inhibitors with Type I RAF inhibitors. One novel ERK inhibitor BVD-523 with two Type I RAF inhibitors, Dabrafenib (GSK2118436) and Vemurafenib (PLX4032), and a Type II inhibitor TAK-632, in two BRAF V600E mutant melanoma cell lines, A375 and G-361. A second, mechanistically distinct, ERK inhibitor (SCH772984) also was tested in combination with Dabrafenib (GSK2118436) and Vemurafenib (PLX4032).

[0260] Single agent proliferation assays were first performed to select an appropriate concentration range for the combination studies. While both cell lines had a similar level of sensitivity to paclitaxel, G-361 cells appeared 4-to-6-fold less sensitive to both ERK and RAF inhibition compared to A375 cells (FIG. 42). IC_{50} results are summarized in Table 18.

Table 18 – Single Agent IC_{50} Values for Tested Compounds

Date reçue/Date received 2024-05-31

Compound	Cell Line	
	A375	G-361
Dabrafenib*	~ 0.0007	~0.0014
Vemurafenib	0.047	0.248
TAK-632	0.026	0.164
BVD-523	0.087	0.344
SCH772984	0.032	0.180
Paclitaxel	0.005	0.007

*The values for dabrafenib should be considered as approximate as the top of the curves were not well defined by the dose range tested.

[0261] Combination interactions between two compounds were assessed across an 8x10 matrix of concentrations using the Loewe Additivity and Bliss Independence Models with Chalice™ Bioinformatics Software (Horizon Discovery Group, Cambridge, MA). Chalice™ enables potential synergistic interactions to be identified by displaying the calculated excess inhibition over that predicted as being additive across the dose matrix as a heat map, and by reporting a quantitative 'Synergy Score' based on the Loewe model.

[0262] In A375 cells (FIG. 43 – FIG. 48), analysis using the Loewe model indicated that combinations with BVD-523 appeared mainly additive. Results using the Bliss method were similar, although this method suggested the presence of a region of mild antagonism at higher concentrations for each combination. In contrast, in G-361 cells (FIG. 49 – FIG. 54), while most interactions across the dose matrix were also additive, both analysis models also revealed small pockets of modest synergy at the mid concentrations.

Date reçue/Date received 2024-05-31

Similar results were obtained with a second mechanistically distinct ERK inhibitor (SCH772984). This supports the notion that the synergies observed in G-361 are likely to be specifically related to inhibition of ERK and not due off-target effects.

[0263] In summary, these results suggest that interactions between BVD-523 and type I and type II RAF inhibitors are at least additive, and in some cases synergistic, in melanoma cell lines carrying a BRAF V600E mutation.

[0264] Synergistic interactions were scored in two ways (FIG. 55 – FIG. 57). Excess activity over that predicted if a combination was additive can be calculated using a simple volume score, which calculates the volume between the measured and the predicted response surface. This volume score shows whether the overall response to a combination is synergistic (positive values), antagonistic (negative values) or additive (values ~ 0). Additionally, a 'Synergy Score' is a positive-gated inhibition-weighted volume over Loewe additivity. This provides an additional prioritization favouring combinations whose synergy occurs at high effect levels, ignoring antagonistic portions of the response surface.

Example 9

Combination Interactions Between ERK inhibitors

[0265] RAF mutant melanoma cell line A375 cells were cultured in DMEM with 10% FBS and seeded into triplicate 96-well plates at an initial density of 2000 cells per well. Combination interactions between ERK inhibitors BVD-523 and SCH772984 were analized after 72 hours as described above in Example 8. Viability was determined using CellTiter-Glo®

Date reçue/Date received 2024-05-31

reagent (Promega, Madison, WI) according to manufacturer's instructions and luminescence was detected using the BMG FLUOstar plate reader (BMG Labtech, Ortenberg, Germany).

[0266] Visualization of the Loewe and Bliss 'excess inhibition' heat maps suggested that the combination of BVD-523 and SCH772984 was mainly additive with windows of potential synergy in mid-range doses (FIG. 58).

[0267] In summary, these results suggest that interactions between BVD-523 and SCH772984 are at least additive, and in some cases synergistic.

Date reçue/Date received 2024-05-31

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Date reçue/Date received 2024-05-31

[0268] Although illustrative embodiments of the present invention have been described herein, it should be understood that the invention is not limited to those described, and that various other changes or modifications may be made by one skilled in the art without departing from the scope or spirit of the invention.

Date reçue/Date received 2024-05-31

What is claimed is:

1. Use of an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is sorafenib or a pharmaceutically acceptable salt thereof, to treat or ameliorate the effects of a cancer in a subject in need thereof.

2. The use according to claim 1, wherein the subject is a mammal.

3. The use according to claim 2, wherein the mammal is selected from the group consisting of humans, primates, farm animals, and domestic animals.

4. The use according to claim 2, wherein the mammal is a human.

5. The use according to claim 1, wherein the BVD-523 or a pharmaceutically acceptable salt thereof is in the form of a pharmaceutical composition further comprising a pharmaceutically acceptable carrier or diluent.

6. The use according to claim 1, wherein the second anti-cancer agent is in the form of a pharmaceutical composition further comprising a pharmaceutically acceptable carrier or diluent.

7. The use according to claim 1, wherein the subject with cancer has a BRAF mutation or is refractory to MAPK pathway inhibitor treatment.

8. The use according to claim 1 further comprising use of at least one additional therapeutic agent selected from the group consisting of an antibody or fragment thereof, a cytotoxic agent, a toxin, a radionuclide, an immunomodulator, a photoactive therapeutic agent, a radiosensitizing agent, a hormone, an anti-angiogenesis agent, and combinations thereof.

Date reçue/Date received 2024-05-31

9. The use according to claim 8, wherein the additional therapeutic agent is an inhibitor of the PI3K/Akt pathway.

10. The use according to claim 9, wherein the inhibitor of the PI3K/Akt pathway is selected from the group consisting of A-674563 (CAS # 552325-73-2), AGL 2263, AMG-319 (Amgen, Thousand Oaks, CA), AS-041164 (5-benzo[1,3]dioxol-5-ylmethylene-thiazolidine-2,4-dione), AS-604850 (5-(2,2-Difluoro-benzo[1,3]dioxol-5-ylmethylene)-thiazolidine-2,4-dione), AS-605240 (5-quinoxilin-6-methylene-1,3-thiazolidine-2,4-dione), AT7867 (CAS # 857531-00-1), benzimidazole series, Genentech (Roche Holdings Inc., South San Francisco, CA), BML-257 (CAS # 32387-96-5), CAL-120 (Gilead Sciences, Foster City, CA), CAL-129 (Gilead Sciences), CAL-130 (Gilead Sciences), CAL-253 (Gilead Sciences), CAL-263 (Gilead Sciences), CAS # 612847-09-3, CAS # 681281-88-9, CAS # 75747-14-7, CAS # 925681-41-0, CAS # 98510-80-6, CCT128930 (CAS # 885499-61-6), CH5132799 (CAS # 1007207-67-1), CHR-4432 (Chroma Therapeutics, Ltd., Abingdon, UK), FPA 124 (CAS # 902779-59-3), GS-1101 (CAL-101) (Gilead Sciences), GSK 690693 (CAS # 937174-76-0), H-89 (CAS # 127243-85-0), Honokiol, IC87114 (Gilead Science), IPI-145 (Intellikine Inc.), KAR-4139 (Karus Therapeutics, Chilworth, UK), KAR-4141 (Karus Therapeutics), KIN-1 (Karus Therapeutics), KT 5720 (CAS # 108068-98-0), Miltefosine, MK-2206 dihydrochloride (CAS # 1032350-13-2), ML-9 (CAS # 105637-50-1), Naltrindole Hydrochloride, OXY-111A (NormOxys Inc., Brighton, MA), perifosine, PHT-427 (CAS # 1191951-57-1), PI3 kinase delta inhibitor, Merck KGaA (Merck & Co., Whitehouse Station, NJ), PI3 kinase delta inhibitors, Genentech (Roche Holdings Inc.), PI3 kinase delta inhibitors, Incozen (Incozen Therapeutics, Pvt. Ltd., Hydrabad, India), PI3 kinase delta inhibitors-2, Incozen (Incozen Therapeutics), PI3 kinase inhibitor, Roche-4 (Roche Holdings Inc.), PI3 kinase inhibitors, Roche (Roche Holdings Inc.), PI3 kinase

Date reçue/Date received 2024-05-31

inhibitors, Roche-5 (Roche Holdings Inc.), PI3-alpha/delta inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd., South San Francisco, CA), PI3-delta inhibitors, Cellzome (Cellzome AG, Heidelberg, Germany), PI3-delta inhibitors, Intellikine (Intellikine Inc., La Jolla, CA), PI3-delta inhibitors, Pathway Therapeutics-1 (Pathway Therapeutics Ltd.), PI3-delta inhibitors, Pathway Therapeutics-2 (Pathway Therapeutics Ltd.), PI3-delta/gamma inhibitors, Cellzome (Cellzome AG), PI3-delta/gamma inhibitors, Cellzome (Cellzome AG), PI3-delta/gamma inhibitors, Intellikine (Intellikine Inc.), PI3-delta/gamma inhibitors, Intellikine (Intellikine Inc.), PI3-delta/gamma inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd.), PI3-delta/gamma inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd.), PI3-gamma inhibitor Evotec (Evotec), PI3-gamma inhibitor, Cellzome (Cellzome AG), PI3-gamma inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd.), PI3K delta/gamma inhibitors, Intellikine-1 (Intellikine Inc.), PI3K delta/gamma inhibitors, Intellikine-1 (Intellikine Inc.), pictilisib (Roche Holdings Inc.), PIK-90 (CAS # 677338-12-4), SC-103980 (Pfizer, New York, NY), SF-1126 (Semafore Pharmaceuticals, Indianapolis, IN), SH-5, SH-6, Tetrahydro Curcumin, TG100-115 (Targegen Inc., San Diego, CA), Triciribine, X-339 (Xcovery, West Palm Beach, FL), XL-499 (Evotech, Hamburg, Germany), pharmaceutically acceptable salts thereof, and combinations thereof.

11. The use according to claim 1, wherein the use of the first and second anti-cancer agents provides a synergistic effect compared to the use of either anti-cancer agent alone.

12. An *in vitro* method of effecting cancer cell death comprising contacting the cancer cell with an effective amount of (i) a first anti-cancer agent, which is BVD-523

Date reçue/Date received 2024-05-31

or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is sorafenib or a pharmaceutically acceptable salt thereof.

13. The method according to claim 12, wherein the cancer cell is a mammalian cancer cell.

14. The method according to claim 13, wherein the mammalian cancer cell emanates from a mammal selected from the group consisting of humans, primates, farm animals, and domestic animals.

15. The method according to claim 13, wherein the mammalian cancer cell is a human cancer cell.

16. The method according to claim 12, wherein the cancer cell emanates from a subject that has a somatic BRAF mutation or is refractory to MAPK pathway inhibitor treatment.

17. The method according to claim 12 further comprising administering at least one additional therapeutic agent selected from the group consisting of an antibody or fragment thereof, a cytotoxic agent, a toxin, a radionuclide, an immunomodulator, a photoactive therapeutic agent, a radiosensitizing agent, a hormone, an anti-angiogenesis agent, and combinations thereof.

18. The method according to claim 17, wherein the additional therapeutic agent is an inhibitor of the PI3K/Akt pathway.

19. The method according to claim 18, wherein the inhibitor of the PI3K/Akt pathway is selected from the group consisting of A-674563 (CAS # 552325-73-2), AGL 2263, AMG-319 (Amgen, Thousand Oaks, CA), AS-041164 (5-benzo[1,3]dioxol-5-

Date reçue/Date received 2024-05-31

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Date reçue/Date received 2024-05-31

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20. The method according to claim 12, wherein contacting the cancer cell with the first and second anti-cancer agents provides a synergistic effect compared to contacting the cancer cell with either anti-cancer agent alone.

21. A kit for treating or ameliorating the effects of a cancer in a subject in need thereof comprising an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is sorafenib a pharmaceutically acceptable salt thereof, packaged together with instructions for their use.

22. The kit according to claim 21, wherein the subject is a mammal.

Date reçue/Date received 2024-05-31

23. The kit according to claim 22, wherein the mammal is selected from the group consisting of humans, primates, farm animals, and domestic animals.

24. The kit according to claim 22, wherein the mammal is a human.

25. The kit according to claim 21, wherein the subject with cancer has a somatic BRAF mutation or is refractory to MAPK pathway inhibitor treatment.

26. The kit according to claim 21 further comprising at least one additional therapeutic agent selected from the group consisting of an antibody or fragment thereof, a cytotoxic agent, a toxin, a radionuclide, an immunomodulator, a photoactive therapeutic agent, a radiosensitizing agent, a hormone, an anti-angiogenesis agent, and combinations thereof.

27. The kit according to claim 26, wherein the additional therapeutic agent is an inhibitor of the PI3K/Akt pathway.

28. The kit according to claim 27, wherein the inhibitor of the PI3K/Akt pathway is selected from the group consisting of A-674563 (CAS # 552325-73-2), AGL 2263, AMG-319 (Amgen, Thousand Oaks, CA), AS-041164 (5-benzo[1,3]dioxol-5-ylmethylene-thiazolidine-2,4-dione), AS-604850 (5-(2,2-Difluoro-benzo[1,3]dioxol-5-ylmethylene)-thiazolidine-2,4-dione), AS-605240 (5-quinoxilin-6-methylene-1,3-thiazolidine-2,4-dione), AT7867 (CAS # 857531-00-1), benzimidazole series, Genentech (Roche Holdings Inc., South San Francisco, CA), BML-257 (CAS # 32387-96-5), CAL-120 (Gilead Sciences, Foster City, CA), CAL-129 (Gilead Sciences), CAL-130 (Gilead Sciences), CAL-253 (Gilead Sciences), CAL-263 (Gilead Sciences), CAS # 612847-09-3, CAS # 681281-88-9, CAS # 75747-14-7, CAS # 925681-41-0, CAS # 98510-80-6, CCT128930 (CAS # 885499-61-6), CH5132799 (CAS # 1007207-67-1),

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Date reçue/Date received 2024-05-31

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29. The kit according to claim 21, wherein administration of the first and second anti-cancer agents provides a synergistic effect compared to administration of either anti-cancer agent alone.

30. A pharmaceutical composition for treating or ameliorating the effects of a cancer in a subject in need thereof, the pharmaceutical composition comprising a pharmaceutically acceptable diluent or carrier and an effective amount of (i) a first anti-cancer agent, which is BVD-523 or a pharmaceutically acceptable salt thereof and (ii) a second anti-cancer agent, which is sorafenib a pharmaceutically acceptable salt thereof, wherein administration of the first and second anti-cancer agents provides a synergistic effect compared to administration of either anti-cancer agent alone.

31. The pharmaceutical composition according to claim 30, wherein the subject is a mammal.

32. The pharmaceutical composition according to claim 31, wherein the mammal is selected from the group consisting of humans, primates, farm animals, and domestic animals.

33. The pharmaceutical composition according to claim 31, wherein the mammal is a human.

Date reçue/Date received 2024-05-31

34. The pharmaceutical composition according to claim 30, wherein the subject with cancer has a somatic BRAF mutation or is refractory to MAPK pathway inhibitor treatment.

35. The pharmaceutical composition according to claim 30 further comprising at least one additional therapeutic agent selected from the group consisting of an antibody or fragment thereof, a cytotoxic agent, a toxin, a radionuclide, an immunomodulator, a photoactive therapeutic agent, a radiosensitizing agent, a hormone, an anti-angiogenesis agent, and combinations thereof.

36. The pharmaceutical composition according to claim 35, wherein the additional therapeutic agent is an inhibitor of the PI3K/Akt pathway.

37. The pharmaceutical composition according to claim 36, wherein the inhibitor of the PI3K/Akt pathway is selected from the group consisting of A-674563 (CAS # 552325-73-2), AGL 2263, AMG-319 (Amgen, Thousand Oaks, CA), AS-041164 (5-benzo[1,3]dioxol-5-ylmethylene-thiazolidine-2,4-dione), AS-604850 (5-(2,2-Difluoro-benzo[1,3]dioxol-5-ylmethylene)-thiazolidine-2,4-dione), AS-605240 (5-quinoxilin-6-methylene-1,3-thiazolidine-2,4-dione), AT7867 (CAS # 857531-00-1), benzimidazole series, Genentech (Roche Holdings Inc., South San Francisco, CA), BML-257 (CAS # 32387-96-5), CAL-120 (Gilead Sciences, Foster City, CA), CAL-129 (Gilead Sciences), CAL-130 (Gilead Sciences), CAL-253 (Gilead Sciences), CAL-263 (Gilead Sciences), CAS # 612847-09-3, CAS # 681281-88-9, CAS # 75747-14-7, CAS # 925681-41-0, CAS # 98510-80-6, CCT128930 (CAS # 885499-61-6), CH5132799 (CAS # 1007207-67-1), CHR-4432 (Chroma Therapeutics, Ltd., Abingdon, UK), FPA 124 (CAS # 902779-59-3), GS-1101 (CAL-101) (Gilead Sciences), GSK 690693 (CAS # 937174-76-0), H-89 (CAS # 127243-85-0), Honokiol, IC87114 (Gilead Science), IPI-

Date reçue/Date received 2024-05-31

145 (Intellikine Inc.), KAR-4139 (Karus Therapeutics, Chilworth, UK), KAR-4141 (Karus Therapeutics), KIN-1 (Karus Therapeutics), KT 5720 (CAS # 108068-98-0), Miltefosine, MK-2206 dihydrochloride (CAS # 1032350-13-2), ML-9 (CAS # 105637-50-1), Naltrindole Hydrochloride, OXY-111A (NormOxys Inc., Brighton, MA), perifosine, PHT-427 (CAS # 1191951-57-1), PI3 kinase delta inhibitor, Merck KGaA (Merck & Co., Whitehouse Station, NJ), PI3 kinase delta inhibitors, Genentech (Roche Holdings Inc.), PI3 kinase delta inhibitors, Incozen (Incozen Therapeutics, Pvt. Ltd., Hydrabad, India), PI3 kinase delta inhibitors-2, Incozen (Incozen Therapeutics), PI3 kinase inhibitor, Roche-4 (Roche Holdings Inc.), PI3 kinase inhibitors, Roche (Roche Holdings Inc.), PI3 kinase inhibitors, Roche-5 (Roche Holdings Inc.), PI3-alpha/delta inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd., South San Francisco, CA), PI3-delta inhibitors, Cellzome (Cellzome AG, Heidelberg, Germany), PI3-delta inhibitors, Intellikine (Intellikine Inc., La Jolla, CA), PI3-delta inhibitors, Pathway Therapeutics-1 (Pathway Therapeutics Ltd.), PI3-delta inhibitors, Pathway Therapeutics-2 (Pathway Therapeutics Ltd.), PI3-delta/gamma inhibitors, Cellzome (Cellzome AG), PI3-delta/gamma inhibitors, Cellzome (Cellzome AG), PI3-delta/gamma inhibitors, Intellikine (Intellikine Inc.), PI3-delta/gamma inhibitors, Intellikine (Intellikine Inc.), PI3-delta/gamma inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd.), PI3-delta/gamma inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd.), PI3-gamma inhibitor Evotec (Evotec), PI3-gamma inhibitor, Cellzome (Cellzome AG), PI3-gamma inhibitors, Pathway Therapeutics (Pathway Therapeutics Ltd.), PI3K delta/gamma inhibitors, Intellikine-1 (Intellikine Inc.), PI3K delta/gamma inhibitors, Intellikine-1 (Intellikine Inc.), pictilisib (Roche Holdings Inc.), PIK-90 (CAS # 677338-12-4), SC-103980 (Pfizer, New York, NY), SF-1126 (Semafore Pharmaceuticals, Indianapolis, IN), SH-5, SH-6, Tetrahydro

Date reçue/Date received 2024-05-31

Curcumin, TG100-115 (Targegen Inc., San Diego, CA), Triciribine, X-339 (Xcovery, West Palm Beach, FL), XL-499 (Evotech, Hamburg, Germany), pharmaceutically acceptable salts thereof, and combinations thereof.

38. The pharmaceutical composition according to claim 30, which is in a unit dosage form comprising both anti-cancer agents.

39. The pharmaceutical composition according to claim 30 in which the first anti-cancer agent is in a first unit dosage form and the second anti-cancer agent is in a second unit dosage form, separate from the first.

40. The pharmaceutical composition according to claim 30, wherein the first and second anti-cancer agents are formulated for co-administration to the subject.

41. The pharmaceutical composition according to claim 30, wherein the first and second anti-cancer agents are formulated for serial administration to the subject.

42. The pharmaceutical composition according to claim 41, wherein the first anti-cancer agent is formulated for administration to the subject before the second anti-cancer agent.

43. The pharmaceutical composition according to claim 41, wherein the second anti-cancer agent is formulated for administration to the subject before the first anti-cancer agent.

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DEMANDE OU BREVET VOLUMINEUX

LA PRÉSENTE PARTIE DE CETTE DEMANDE OU CE BREVET COMPREND PLUS D'UN TOME.

CECI EST LE TOME 1 DE 2
CONTENANT LES PAGES 1 À 171

NOTE : Pour les tomes additionels, veuillez contacter le Bureau canadien des brevets

JUMBO APPLICATIONS/PATENTS

THIS SECTION OF THE APPLICATION/PATENT CONTAINS MORE THAN ONE VOLUME

THIS IS VOLUME 1 OF 2
CONTAINING PAGES 1 TO 171

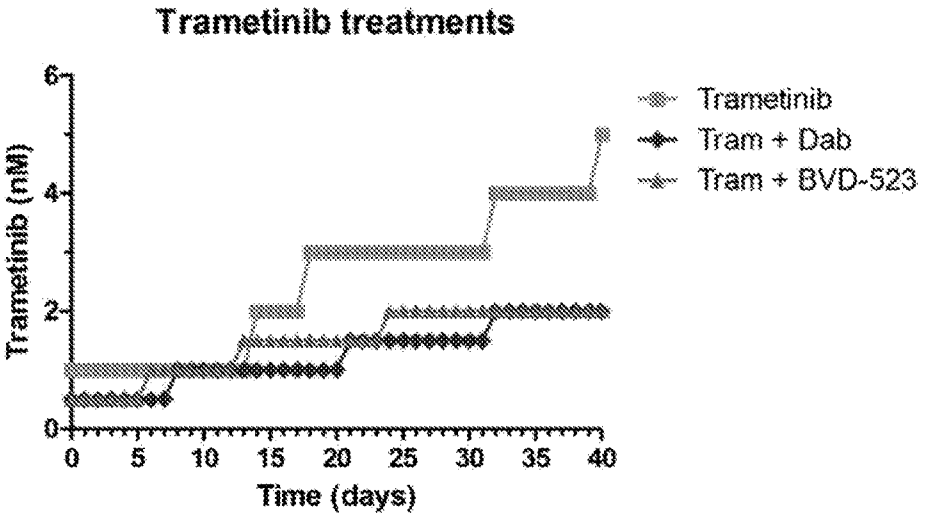
NOTE: For additional volumes, please contact the Canadian Patent Office

NOM DU FICHIER / FILE NAME :

NOTE POUR LE TOME / VOLUME NOTE:

FIG. 1

A


Trametinib treatments
Trametinib (nM)
0
2
4
6
0 5 10 15 20 25 30 35 40
Time (days)
Trametinib
Tram + Dab
Tram + BVD-523

B

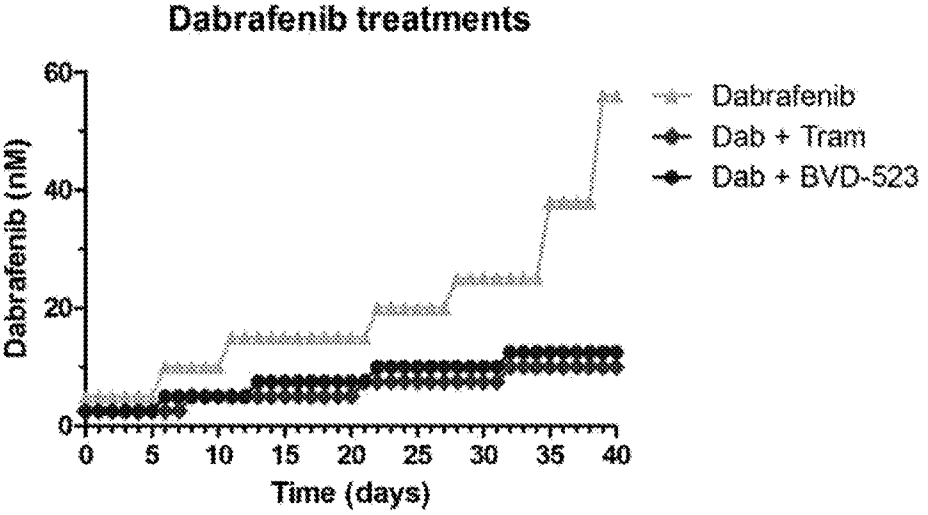

Dabrafenib treatments
Dabrafenib (nM)
0
20
40
60
0 5 10 15 20 25 30 35 40
Time (days)
Dabrafenib
Dab + Tram
Dab + BVD-523

FIG. 1, Con't

C

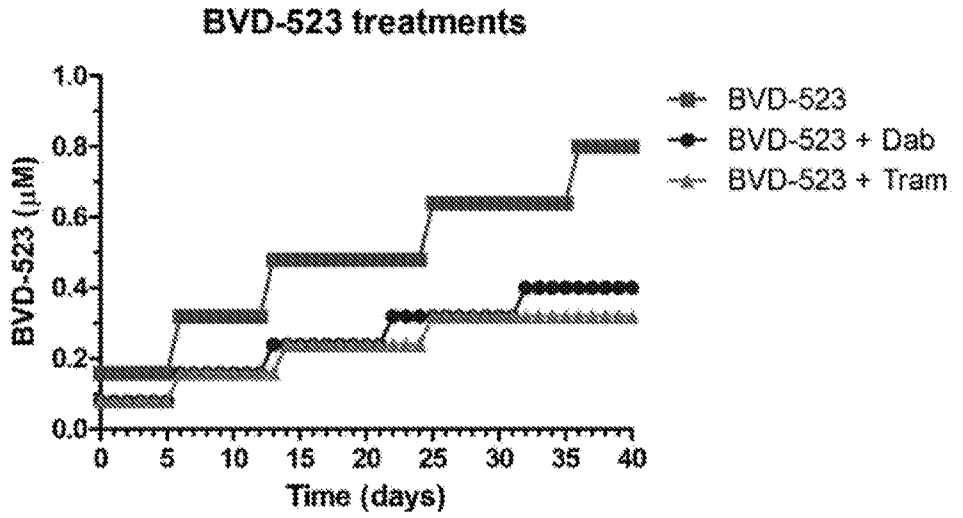

BVD-523 treatments
BVD-523 (μM)
1.0
0.8
0.6
0.4
0.2
0.0
0
5
10
15
20
25
30
35
40
Time (days)
BVD-523
BVD-523 + Dab
BVD-523 + Tram

FIG. 2

A

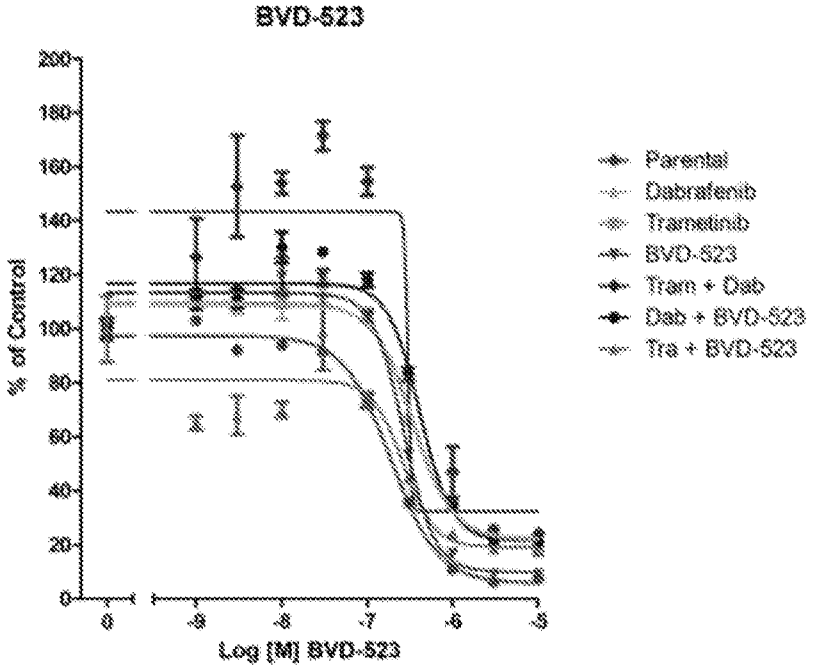

BVD-523
% of Control
Log [M] BVD-523
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 2, Con't

B

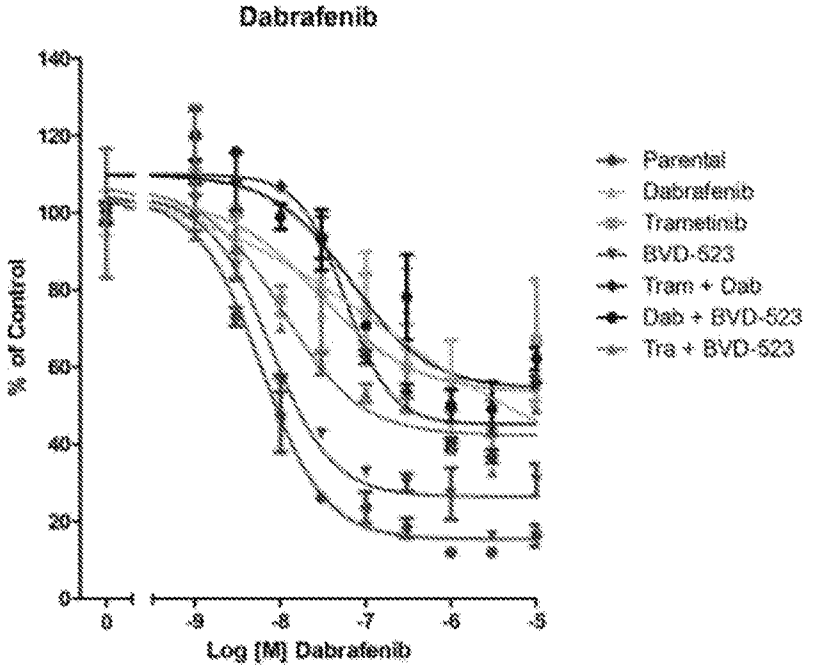

Dabrafenib
% of Control
Log [M] Dabrafenib
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 2, Con't

C

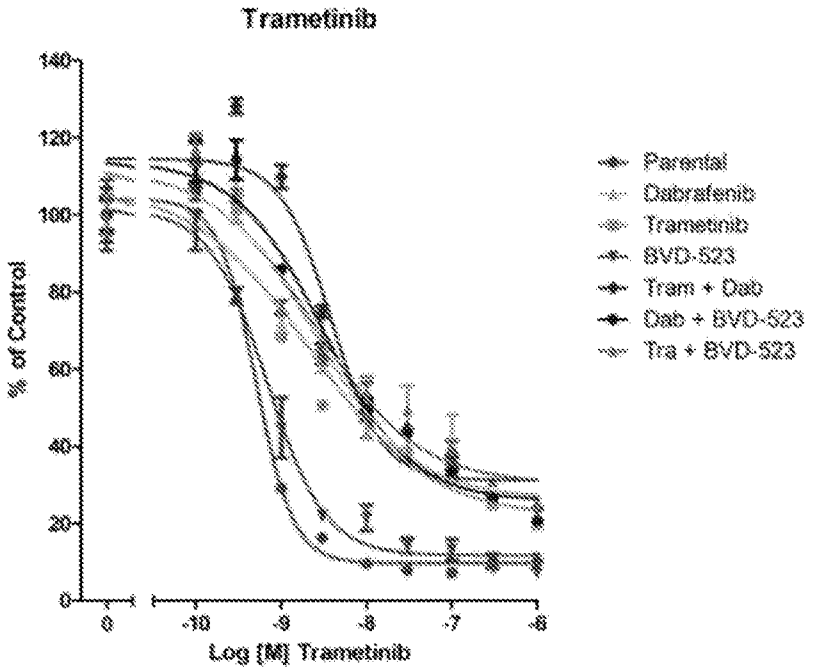

Trametinib
% of Control
Log [M] Trametinib
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 2, Con't

D

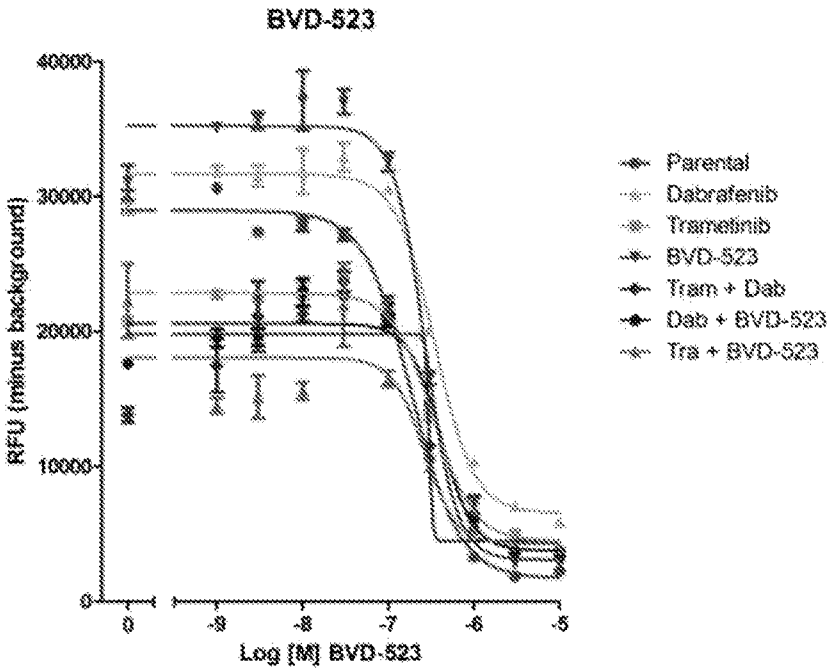

BVD-523
40000
30000
20000
10000
0
RFU (minus background)
0
-9
-8
-7
-6
-5
Log [M] BVD-523
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 2, Con't

E

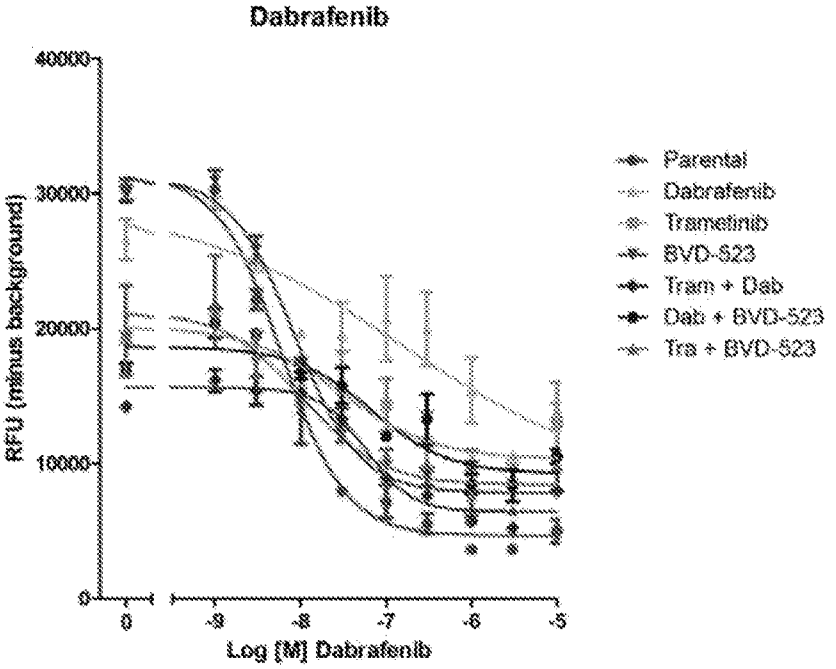

Dabrafenib
RFU (minus background)
40000
30000
20000
10000
0
0
-9
-8
-7
-6
-5
Log [M] Dabrafenib
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 2, Con't

F

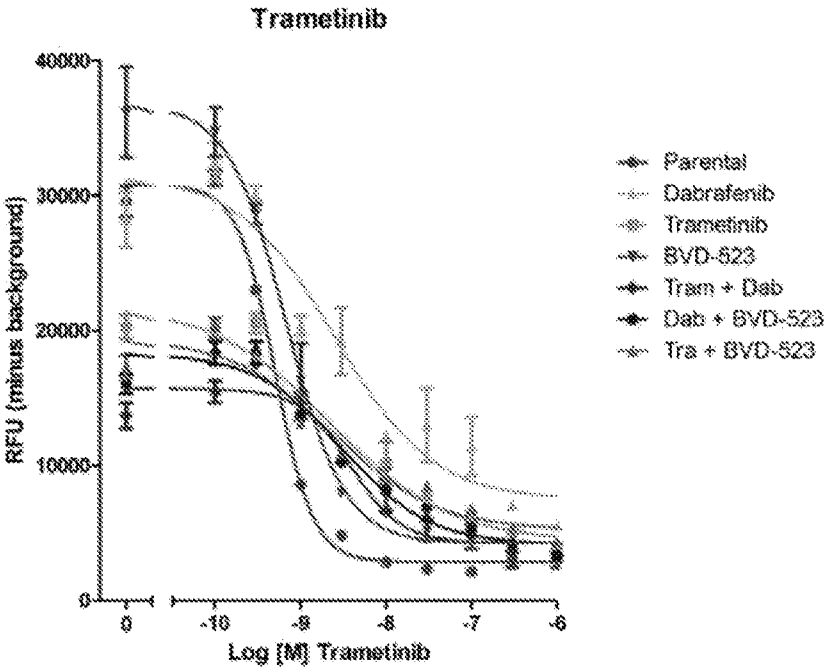

Trametinib
RFU (minus background)
40000
30000
20000
10000
0
0
-10
-9
-8
-7
-6
Log [M] Trametinib
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 2, Con't

G

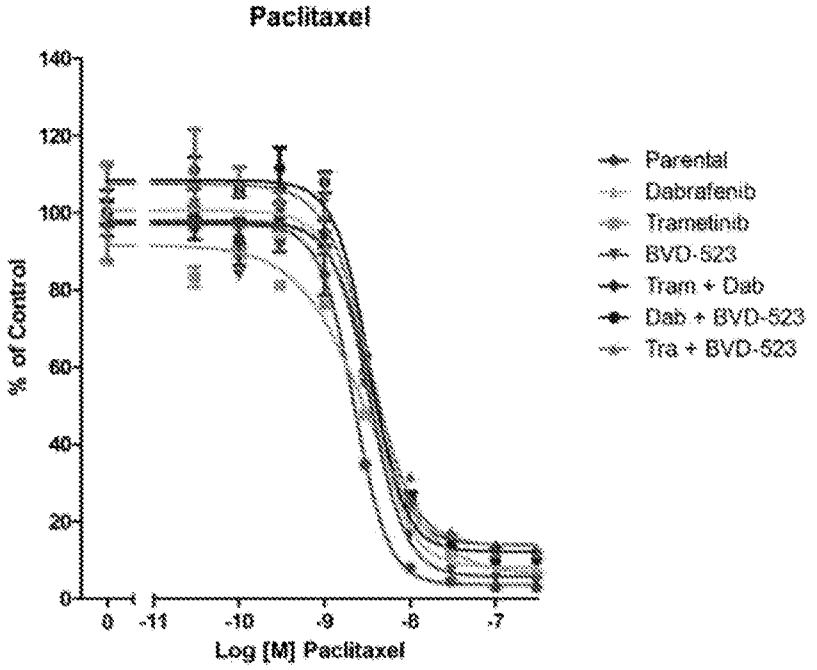

Paclitaxel
% of Control
Log [M] Paclitaxel
0
20
40
60
80
100
120
140
-11
-10
-9
-8
-7
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 2, Con't

H

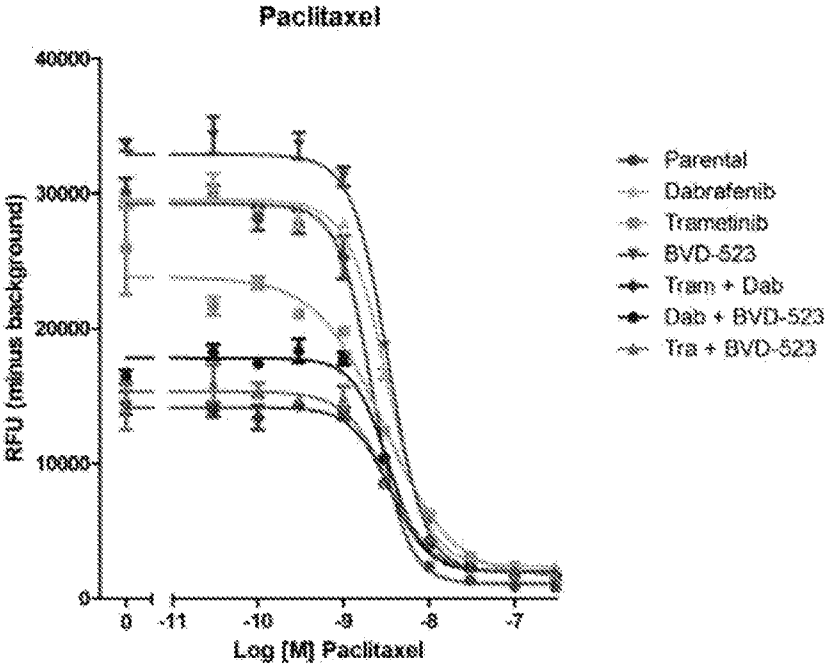
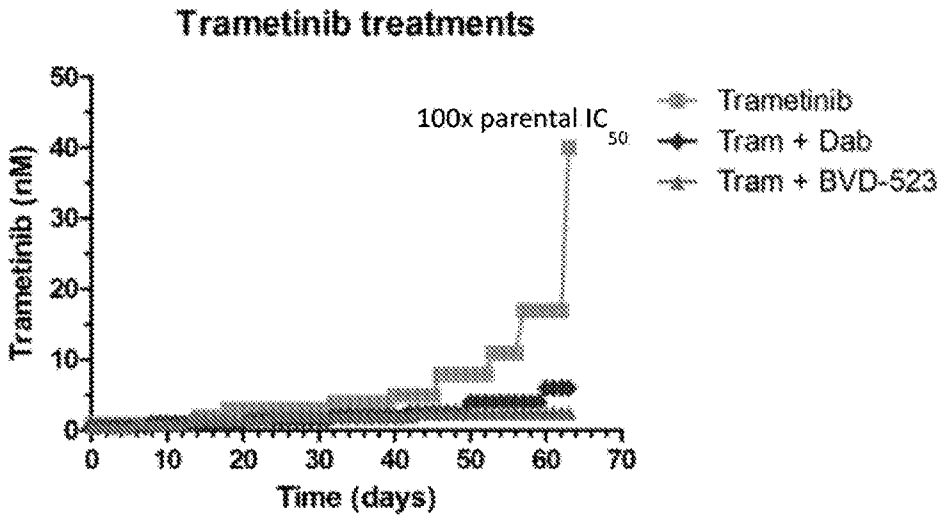

Paclitaxel
RFU (minus background)
40000
30000
20000
10000
0
0
-11
-10
-9
-8
-7
Log [M] Paclitaxel
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 3

A


Trametinib treatments
Trametinib (nM)
Time (days)
100x parental IC50
Trametinib
Tram + Dab
Tram + BVD-523

B

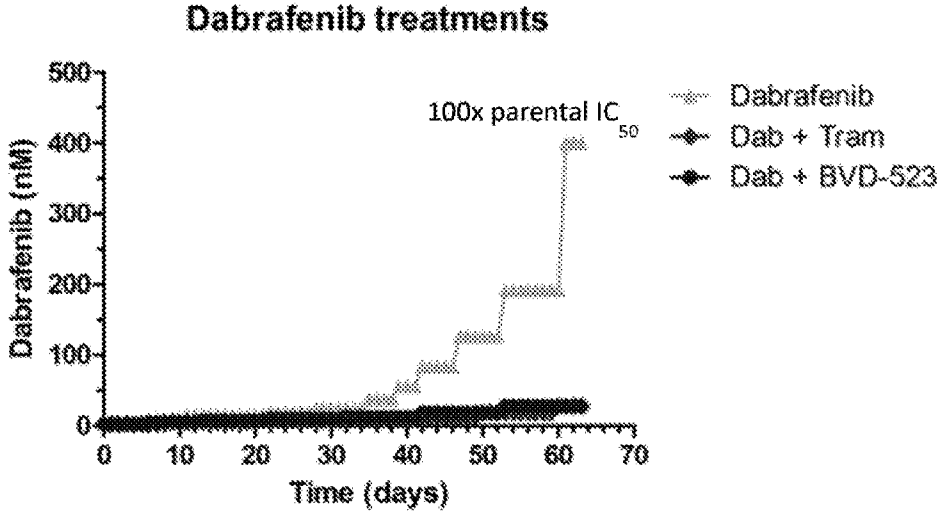
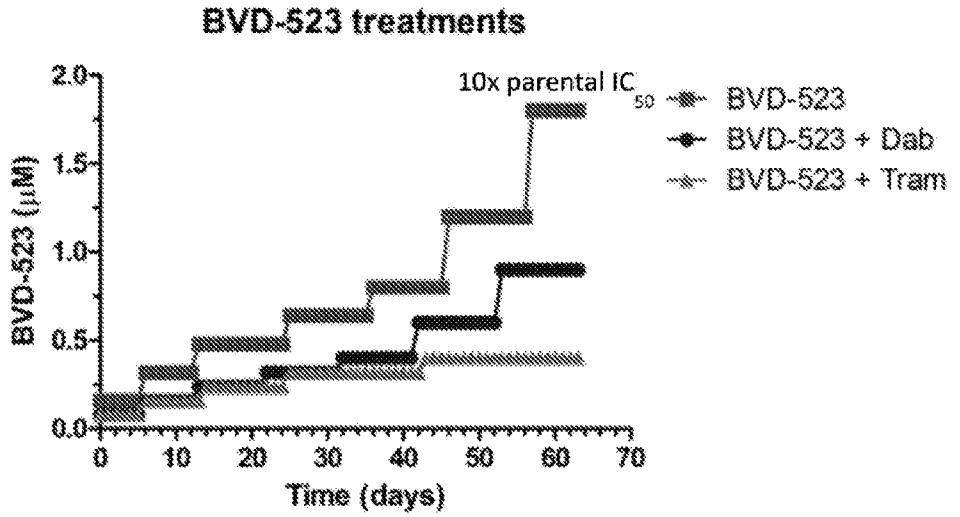

Dabrafenib treatments
Dabrafenib (nM)
Time (days)
100x parental IC50
Dabrafenib
Dab + Tram
Dab + BVD-523

FIG. 3, Con't

C


BVD-523 treatments
10x parental IC50
BVD-523
BVD-523 + Dab
BVD-523 + Tram
BVD-523 (μM)
2.0
1.5
1.0
0.5
0.0
0
10
20
30
40
50
60
70
Time (days)

D

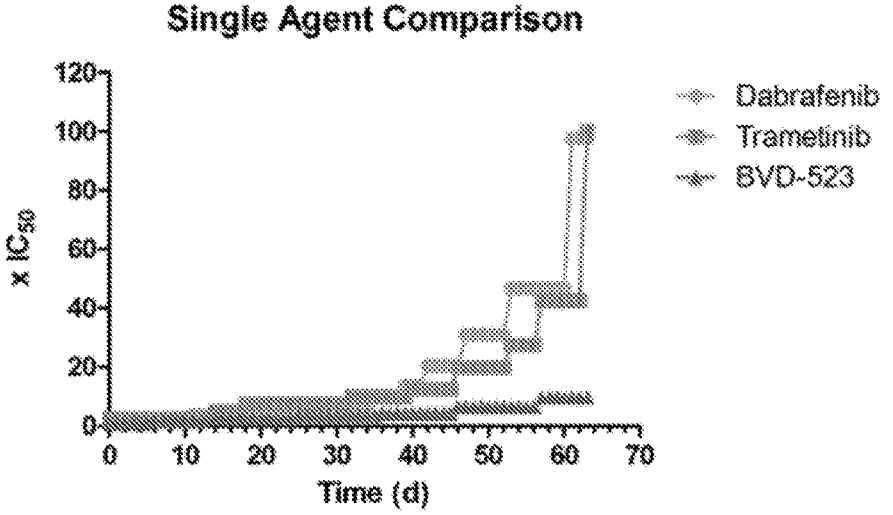

Single Agent Comparison
Dabrafenib
Trametinib
BVD-523
x IC50
120
100
80
60
40
20
0
0
10
20
30
40
50
60
70
Time (d)

FIG. 4

A

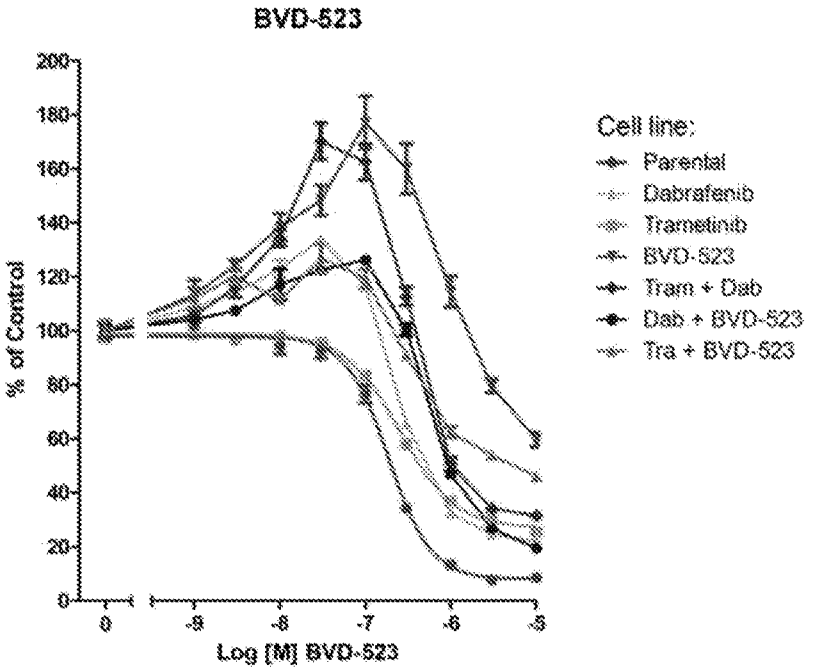

BVD-523
% of Control
Log [M] BVD-523
Cell line:
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 4, Con't

B

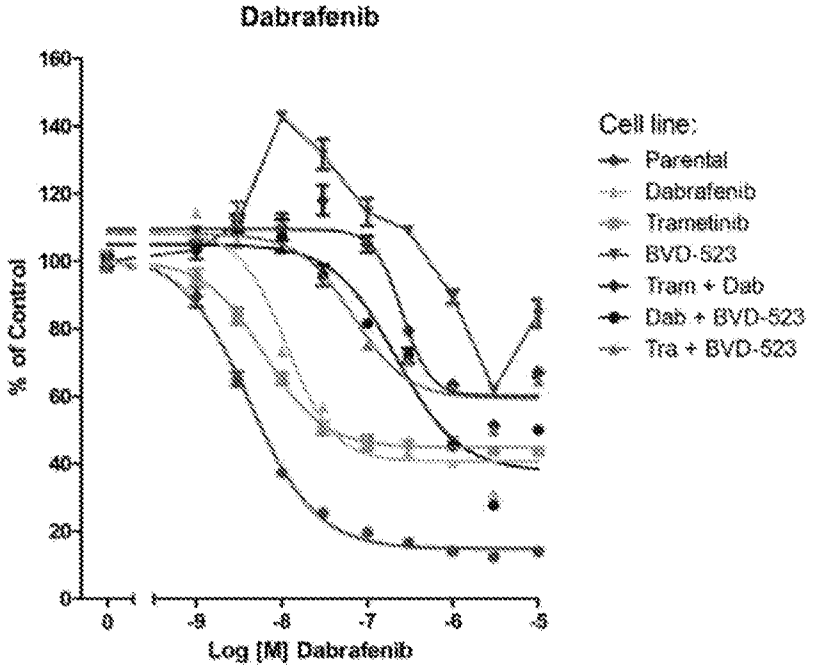

Dabrafenib
% of Control
160
140
120
100
80
60
40
20
0
0
-9
-8
-7
-6
-5
Log [M] Dabrafenib
Cell line:
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 4, Con't

C

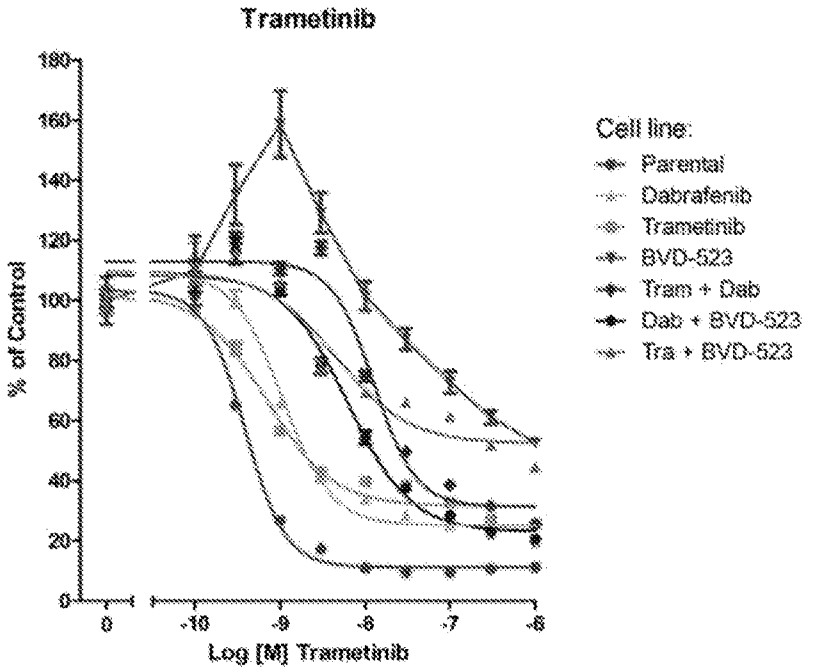

Trametinib
% of Control
Log [M] Trametinib
Cell line:
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 4, Con't

D

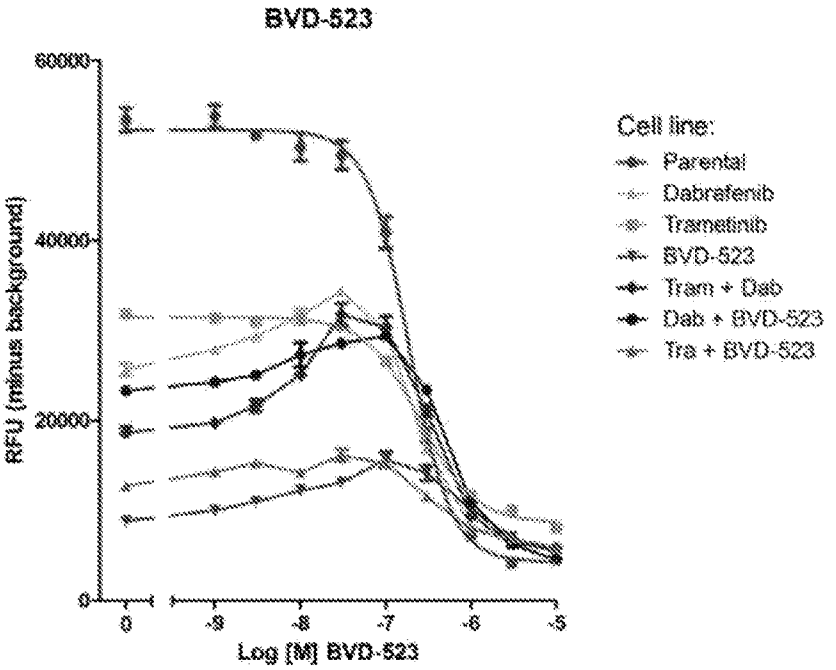

BVD-523
60000
40000
20000
0
RFU (minus background)
0
-9
-8
-7
-6
-5
Log [M] BVD-523
Cell line:
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 4, Con't

E

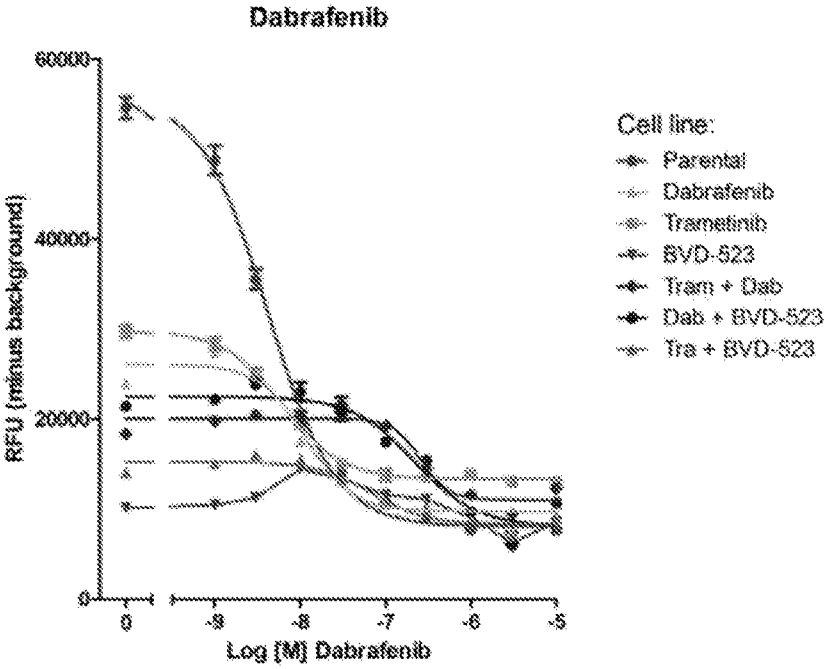

Dabrafenib
60000
40000
20000
0
RFU (minus background)
0
-9
-8
-7
-6
-5
Log [M] Dabrafenib
Cell line:
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 4, Con't

F

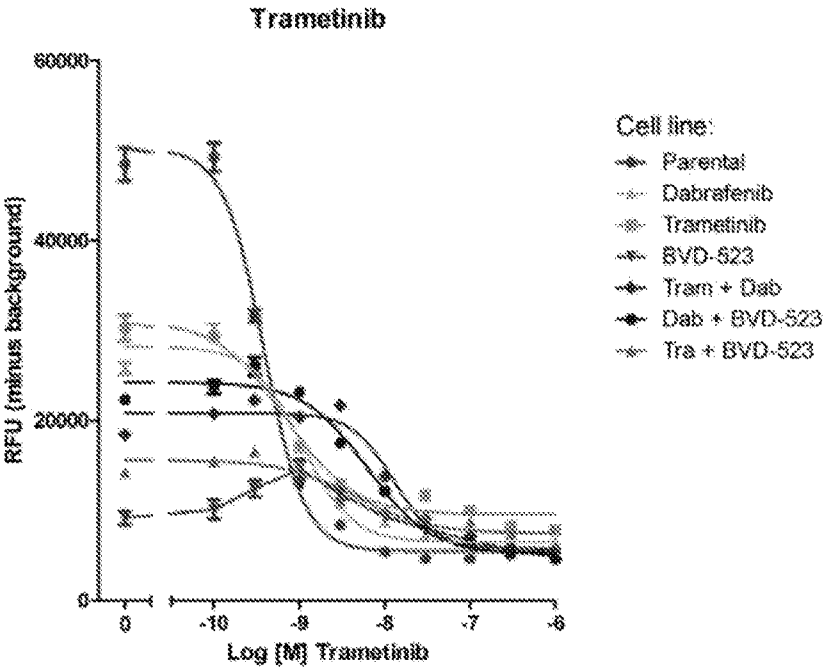

Trametinib
60000
40000
20000
0
RFU (minus background)
0
-10
-9
-8
-7
-6
Log [M] Trametinib
Cell line:
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 4, Con't

G

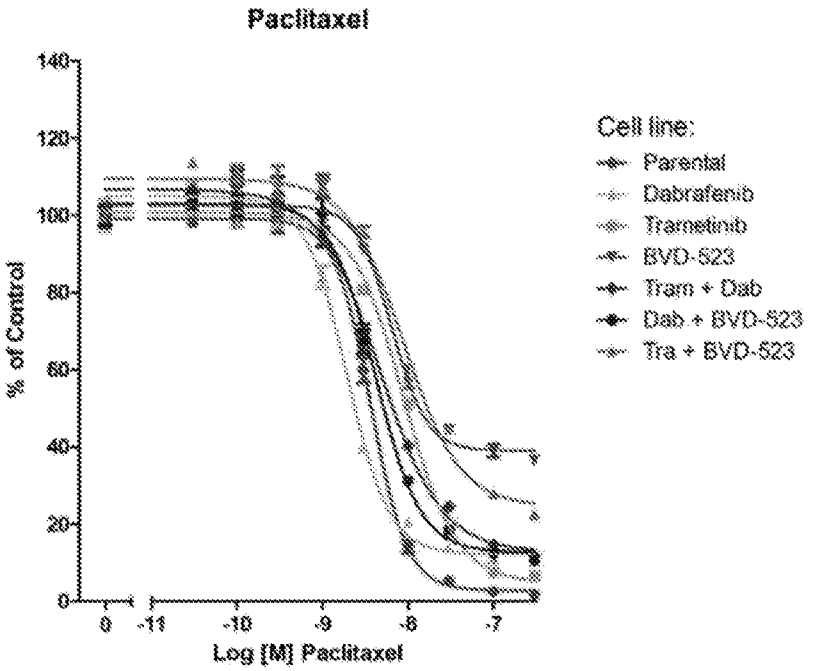

Paclitaxel
% of Control
140
120
100
80
60
40
20
0
0
-11
-10
-9
-8
-7
Log [M] Paclitaxel
Cell line:
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 4, Con't

H

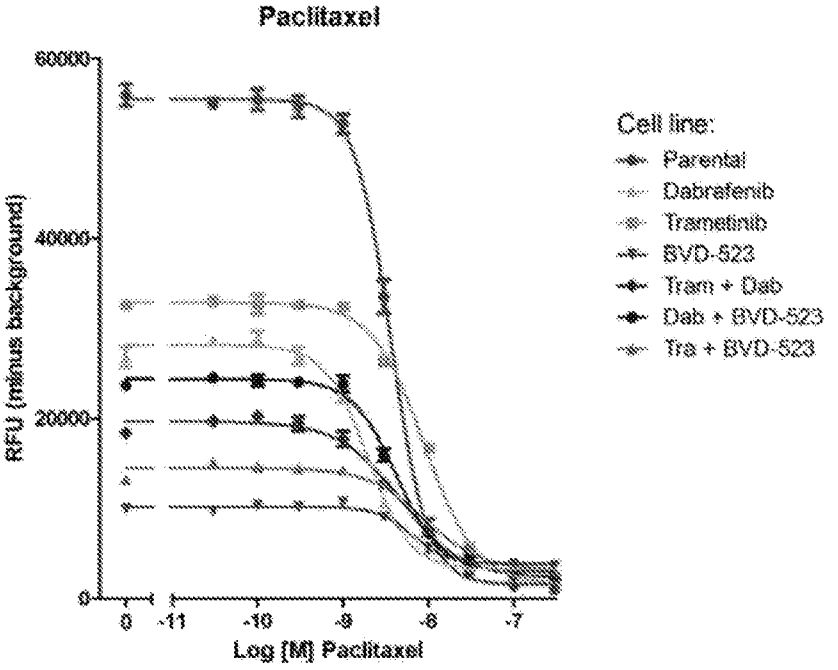

Paclitaxel
RFU (minus background)
60000
40000
20000
0
0
-11
-10
-9
-8
-7
Log [M] Paclitaxel
Cell line:
Parental
Dabrafenib
Trametinib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 5

A

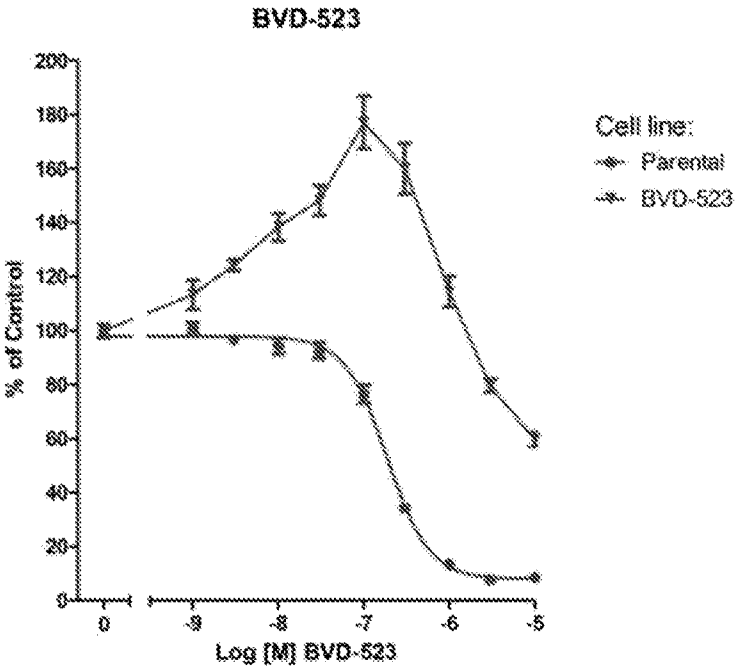


FIG. 5, Con't

B

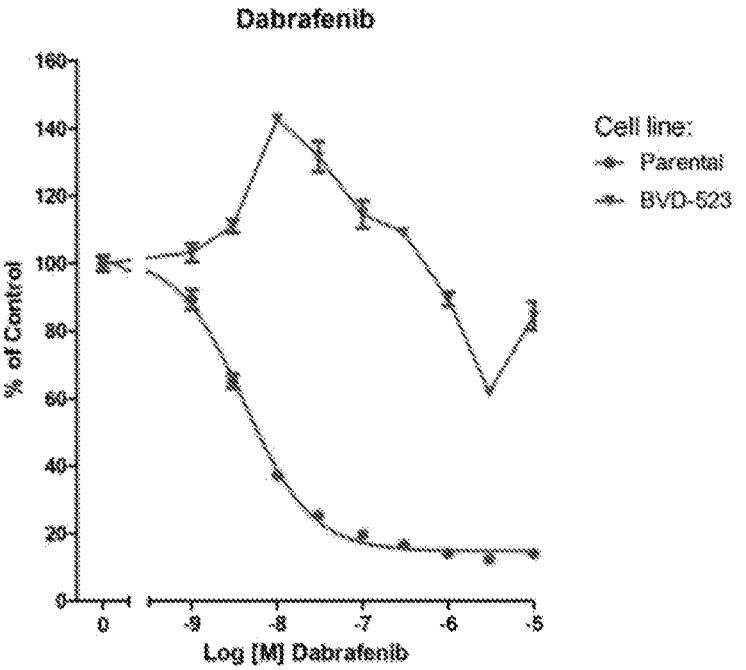

Dabrafenib
% of Control
160
140
120
100
80
60
40
20
0
0
-9
-8
-7
-6
-5
Log [M] Dabrafenib
Cell line:
Parental
BVD-523

FIG. 5, Con't

C

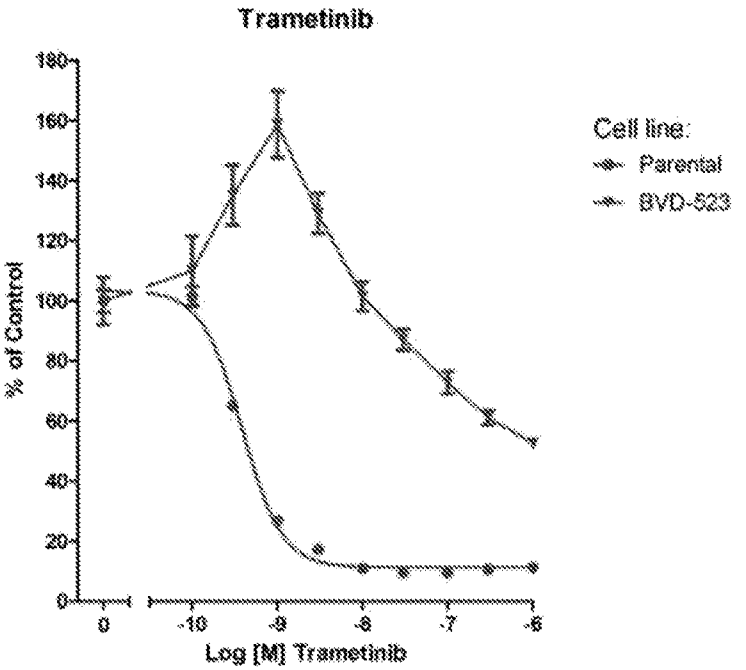

Trametinib
% of Control
180
160
140
120
100
80
60
40
20
0
0
-10
-9
-8
-7
-6
Log [M] Trametinib
Cell line:
Parental
BVD-523

FIG. 5, Con't

D

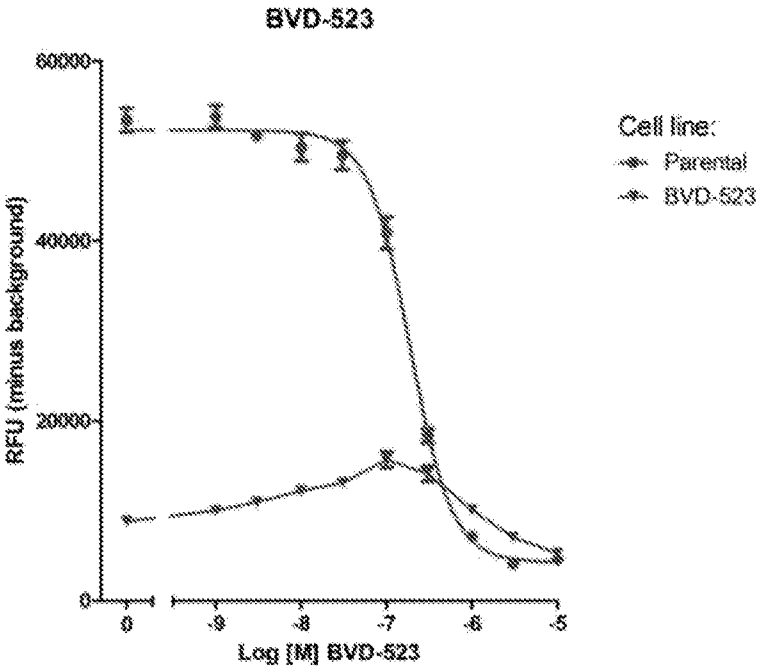

BVD-523
60000
40000
20000
0
RFU (minus background)
0
-9
-8
-7
-6
-5
Log [M] BVD-523
Cell line:
Parental
BVD-523

FIG. 5, Con't

E

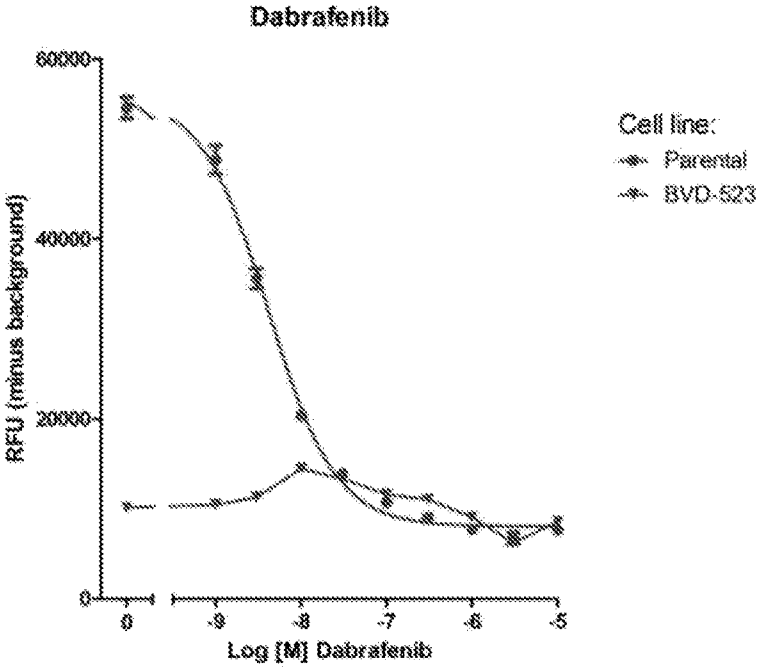

Dabrafenib
60000
40000
20000
0
RFU (minus background)
0
-9
-8
-7
-6
-5
Log [M] Dabrafenib
Cell line:
Parental
BVD-523

FIG. 5, Con't

F

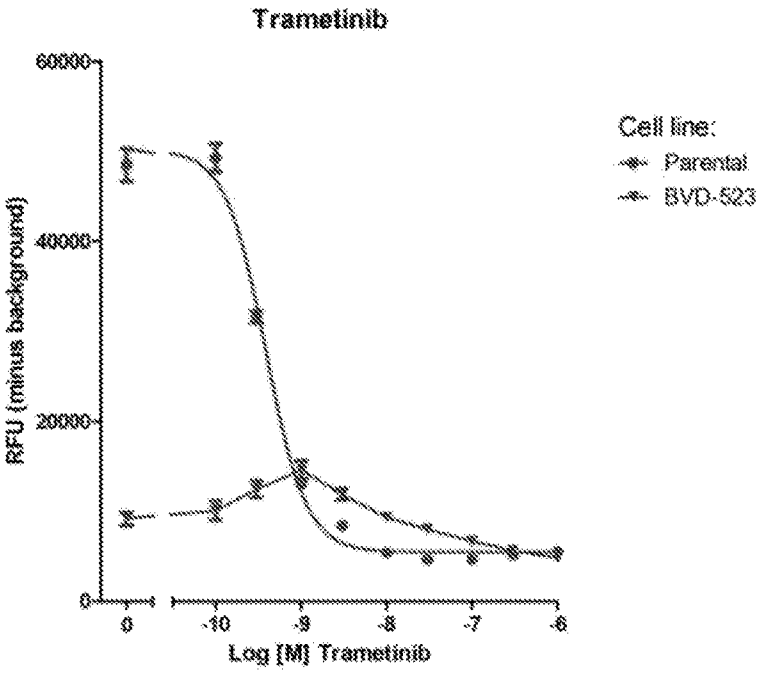

Trametinib
60000
40000
20000
0
RFU (minus background)
0
-10
-9
-8
-7
-6
Log [M] Trametinib
Cell line:
Parental
BVD-523

FIG. 5 Con't

G

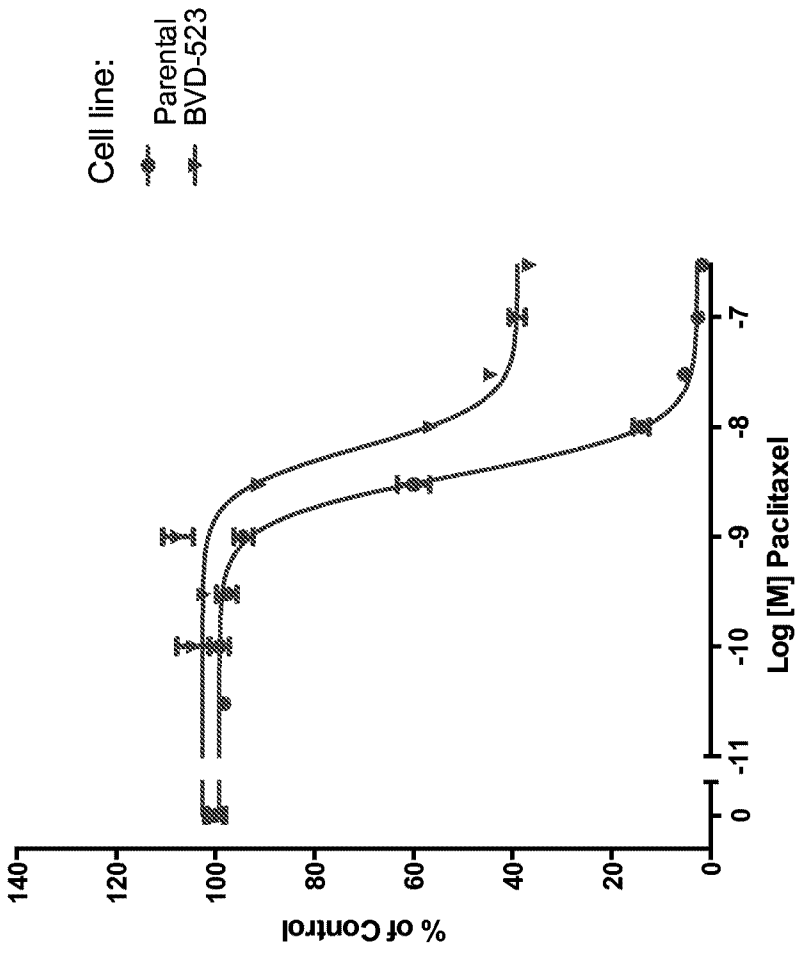

Paclitaxel
Cell line:
Parental
BVD-523
% of Control
140
120
100
80
60
40
20
0
0
-11
-10
-9
-8
-7
Log [M] Paclitaxel

FIG. 5 Con't

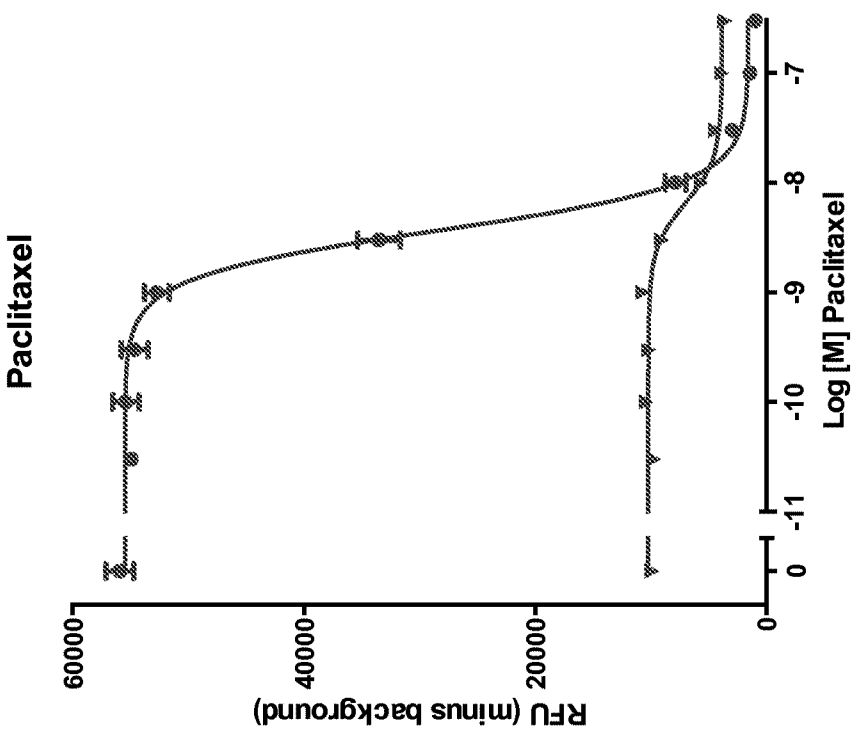

H
Paclitaxel
Cell line:
Parental
BVD-523
RFU (minus background)
60000
40000
20000
0
0
-11
-10
-9
-8
-7
Log [M] Paclitaxel

FIG. 6

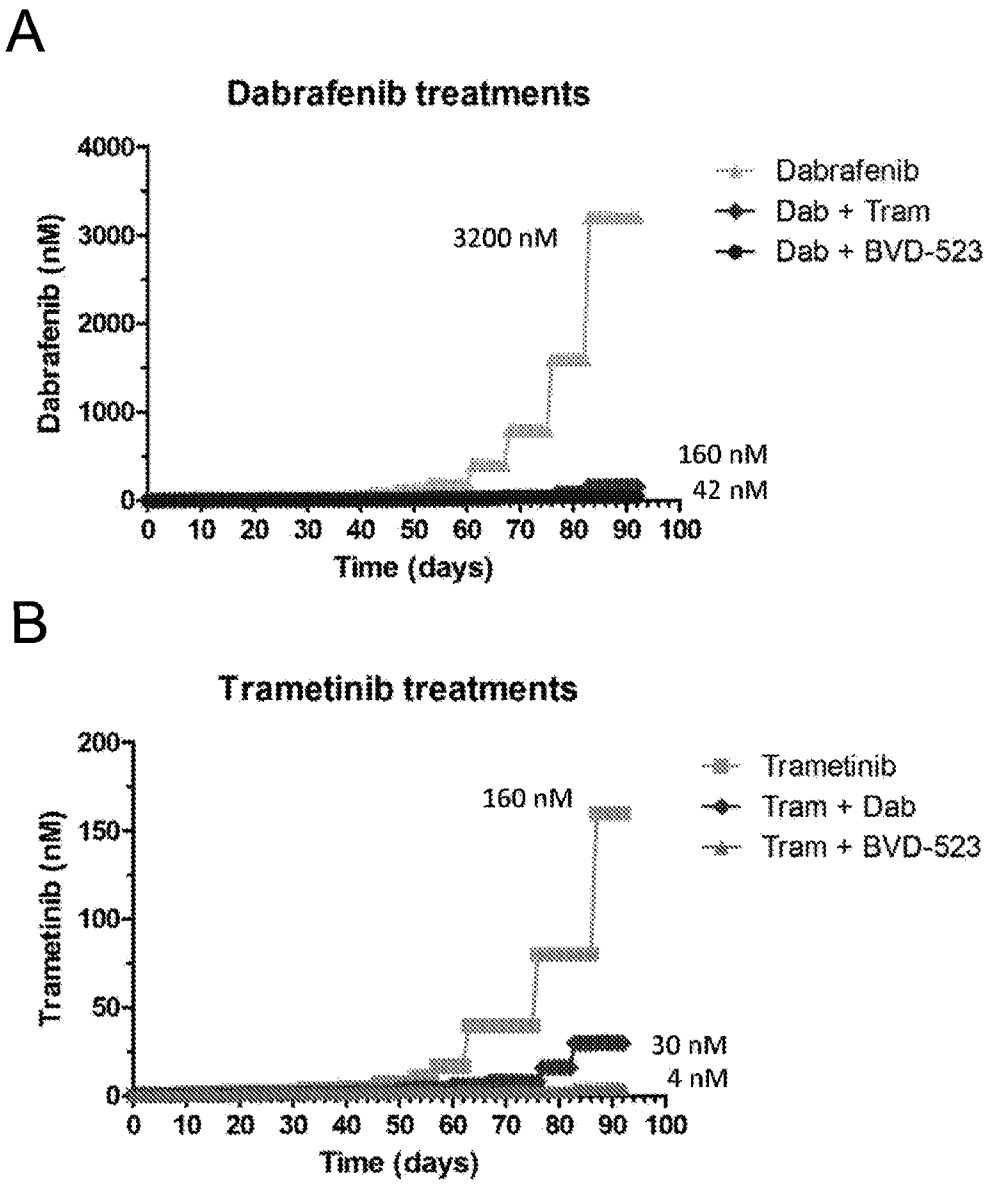
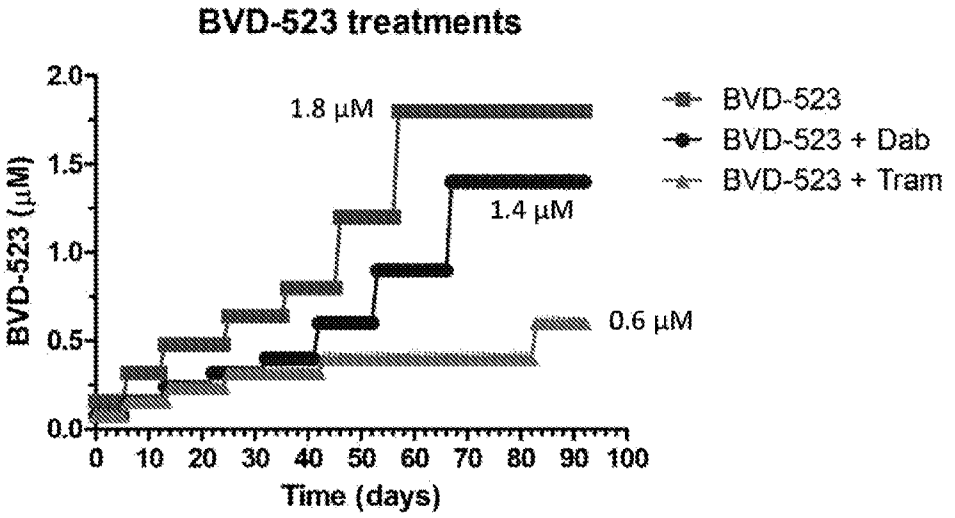

A
Dabrafenib treatments
Dabrafenib (nM)
4000
3000
2000
1000
0
3200 nM
160 nM
42 nM
0 10 20 30 40 50 60 70 80 90 100
Time (days)
Dabrafenib
Dab + Tram
Dab + BVD-523
B
Trametinib treatments
Trametinib (nM)
200
150
100
50
0
160 nM
30 nM
4 nM
0 10 20 30 40 50 60 70 80 90 100
Time (days)
Trametinib
Tram + Dab
Tram + BVD-523

FIG. 6, Con't

C


BVD-523 treatments
BVD-523 (μM)
2.0
1.5
1.0
0.5
0.0
1.8 μM
1.4 μM
0.6 μM
BVD-523
BVD-523 + Dab
BVD-523 + Tram
0 10 20 30 40 50 60 70 80 90 100
Time (days)

D

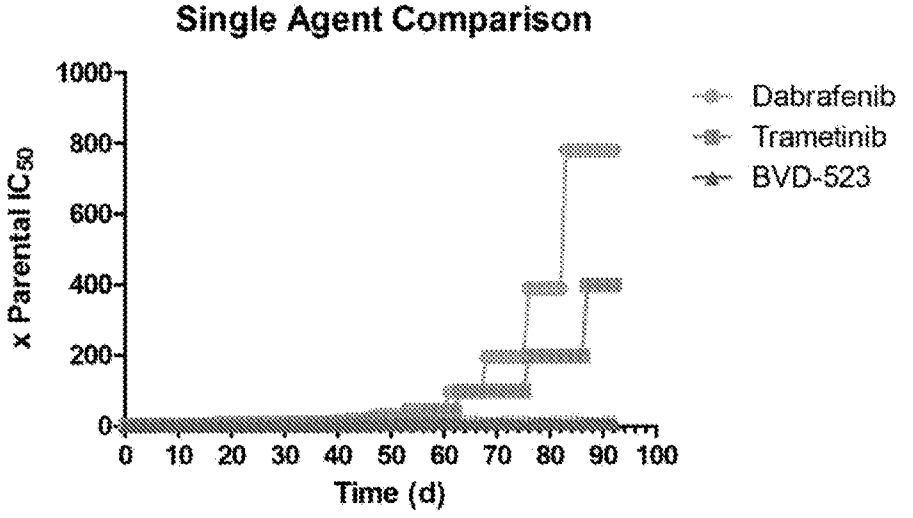

Single Agent Comparison
x Parental IC50
1000
800
600
400
200
0
Dabrafenib
Trametinib
BVD-523
0 10 20 30 40 50 60 70 80 90 100
Time (d)

FIG. 7

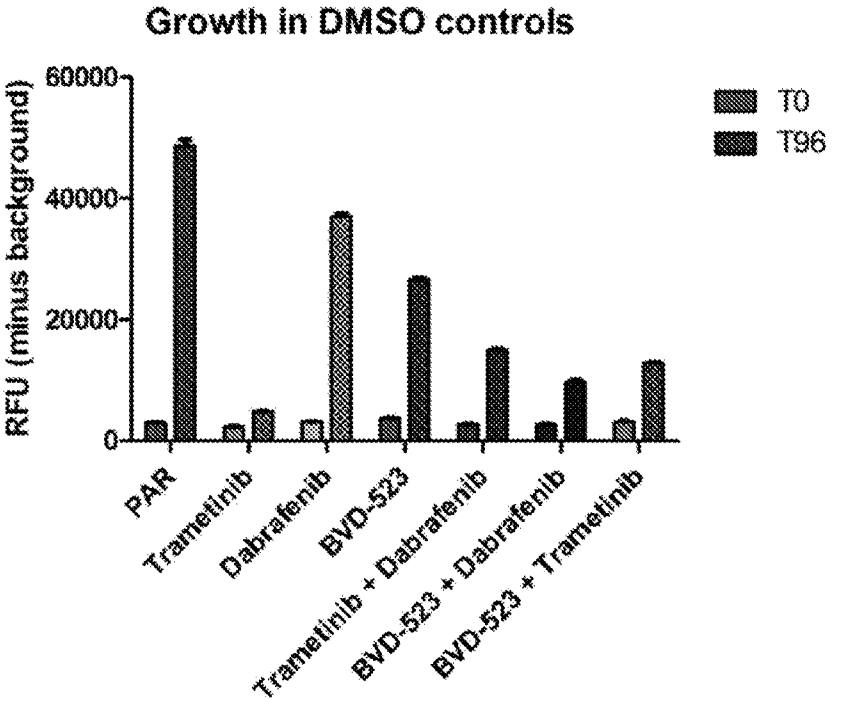

Growth in DMSO controls
RFU (minus background)
60000
40000
20000
0
T0
T96
PAR
Trametinib
Dabrafenib
BVD-523
Trametinib + Dabrafenib
BVD-523 + Dabrafenib
BVD-523 + Trametinib

FIG. 8

A

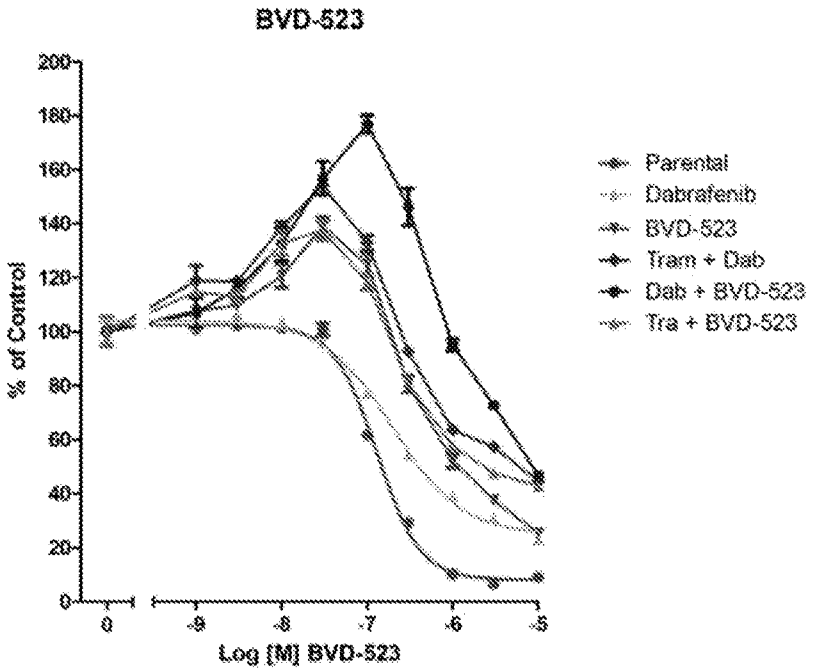

BVD-523
% of Control
Log [M] BVD-523
Parental
Dabrafenib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 8, Con't

B

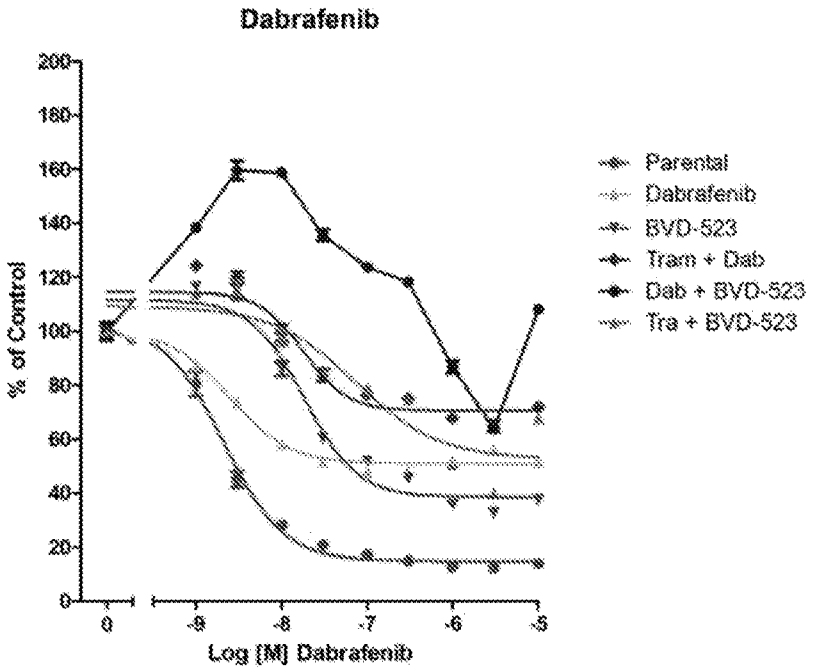

Dabrafenib
% of Control
Log [M] Dabrafenib
Parental
Dabrafenib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 8, Con't

C

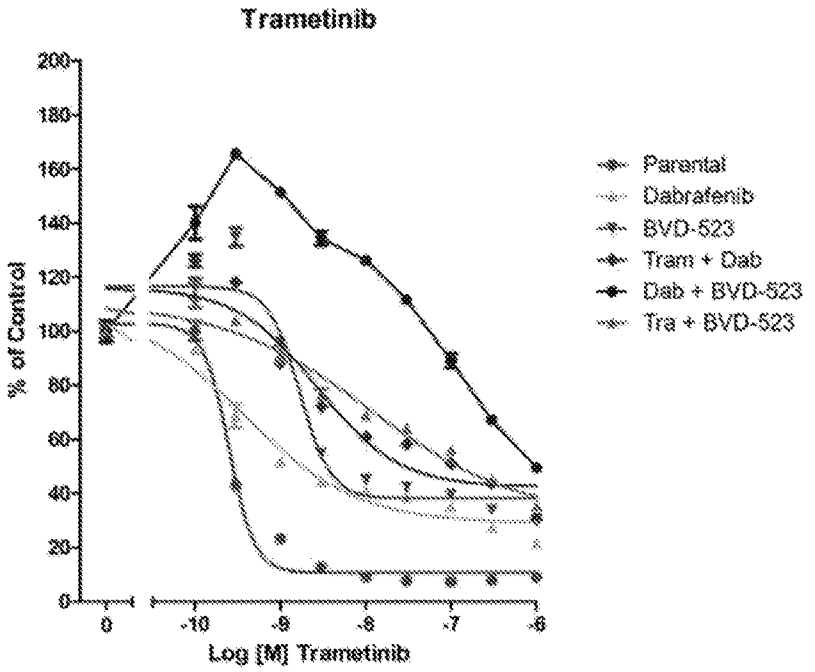

Trametinib
% of Control
Log [M] Trametinib
Parental
Dabrafenib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 8, Con't

D

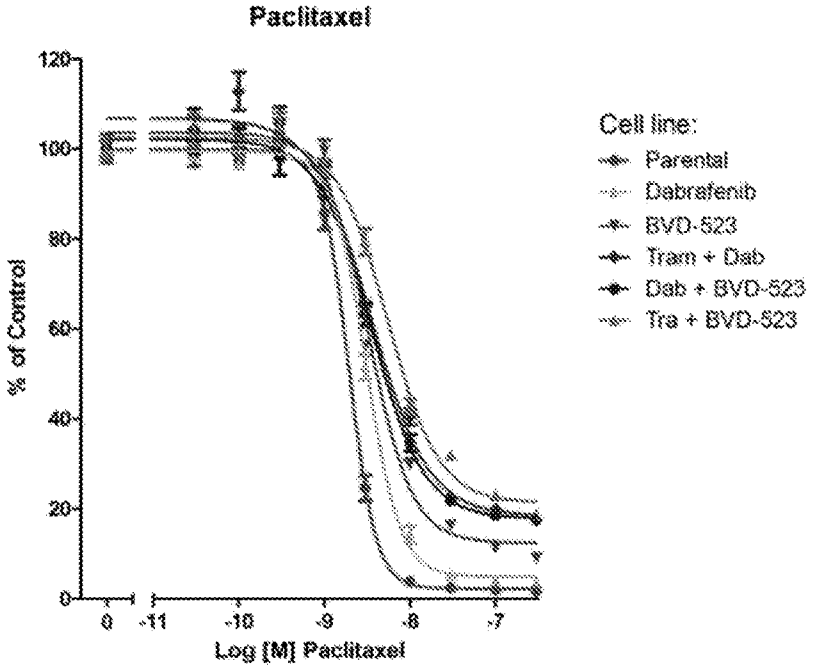

Paclitaxel
% of Control
120
100
80
60
40
20
0
0
-11
-10
-9
-8
-7
Log [M] Paclitaxel
Cell line:
Parental
Dabrafenib
BVD-523
Tram + Dab
Dab + BVD-523
Tra + BVD-523

FIG. 9

A

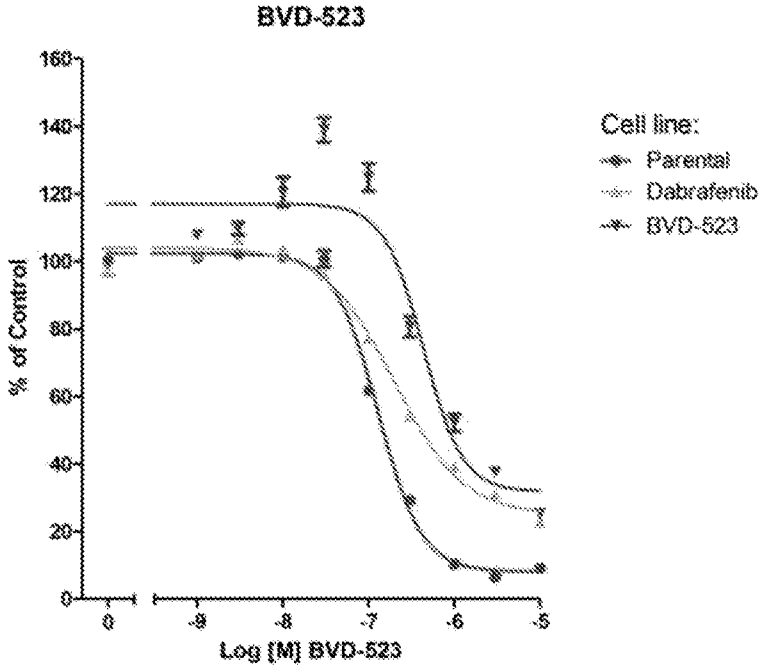

BVD-523
% of Control
Log [M] BVD-523
Cell line:
Parental
Dabrafenib
BVD-523

FIG. 9, Con't

B

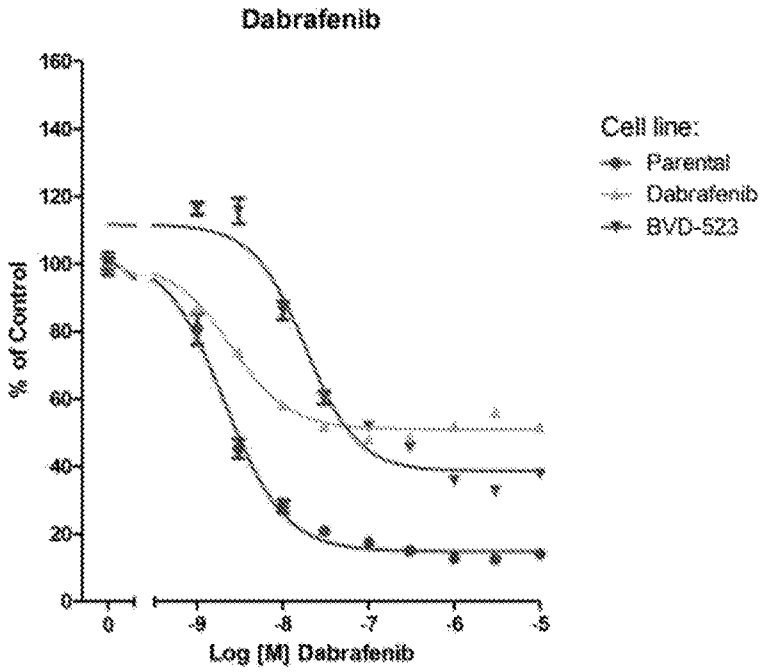

Dabrafenib
% of Control
160
140
120
100
80
60
40
20
0
0
-9
-8
-7
-6
-5
Log [M] Dabrafenib
Cell line:
Parental
Dabrafenib
BVD-523

FIG. 9, Con't

C

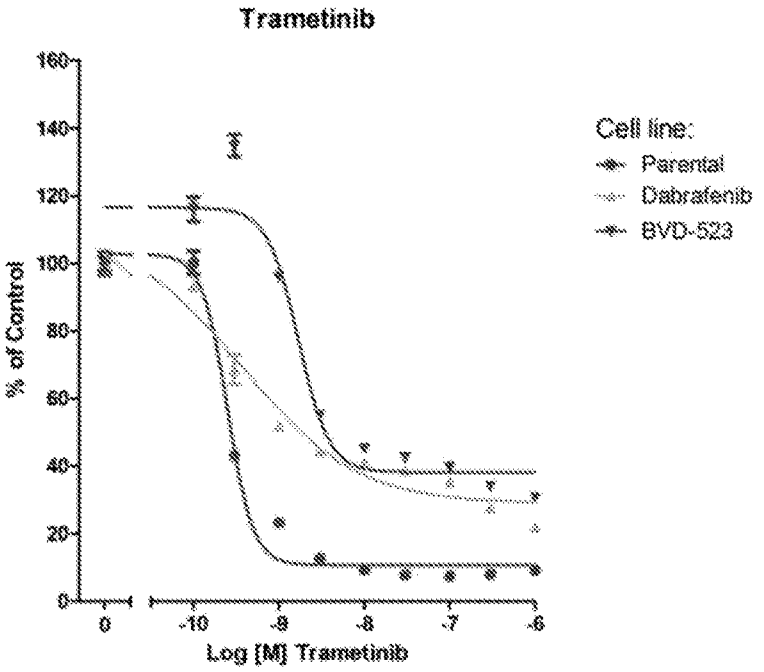

Trametinib
% of Control
160
140
120
100
80
60
40
20
0
0
-10
-9
-8
-7
-6
Log [M] Trametinib
Cell line:
Parental
Dabrafenib
BVD-523

FIG. 9, Con't

D

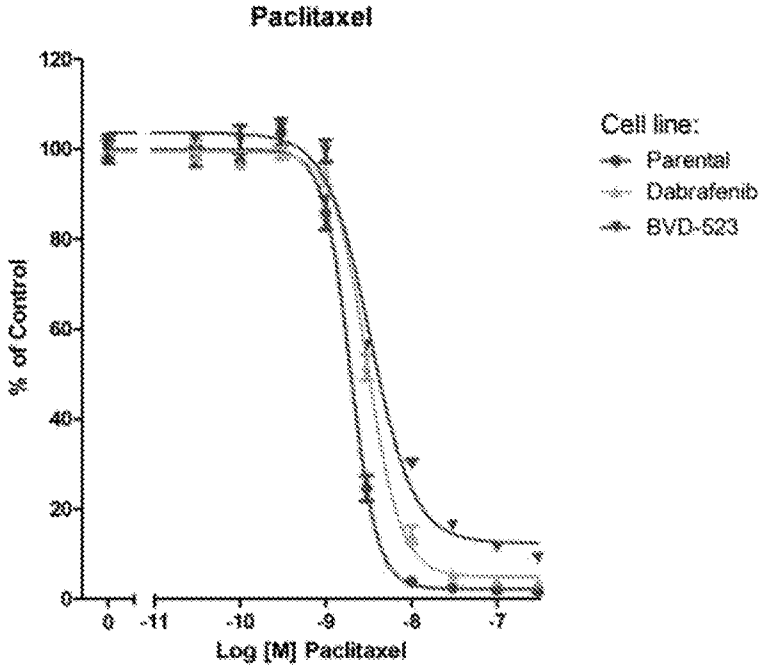

Paclitaxel
% of Control
120
100
80
60
40
20
0
0
-11
-10
-9
-8
-7
Log [M] Paclitaxel
Cell line:
Parental
Dabrafenib
BVD-523

FIG. 10

A

% Inhibition:

Trametinib (nM) \ Dabrafenib (μM)	0	0.001	0.003	0.01	0.03	0.1	0.3	1	3	10
10000	93	93	93	93	94	94	94	96	97	92
1000	87	87	88	88	89	89	90	92	93	88
100	87	88	88	88	89	89	90	91	92	87
10	82	83	83	84	85	86	86	88	89	86
1	67	70	73	78	81	83	84	86	88	86
0.1	-17	3	27	58	72	79	82	85	86	83
0.01	3	-4	15	45	68	76	80	83	85	81
0	0	4	10	43	67	76	79	83	85	82

FIG. 10, Con't

B

Excess over Bliss:

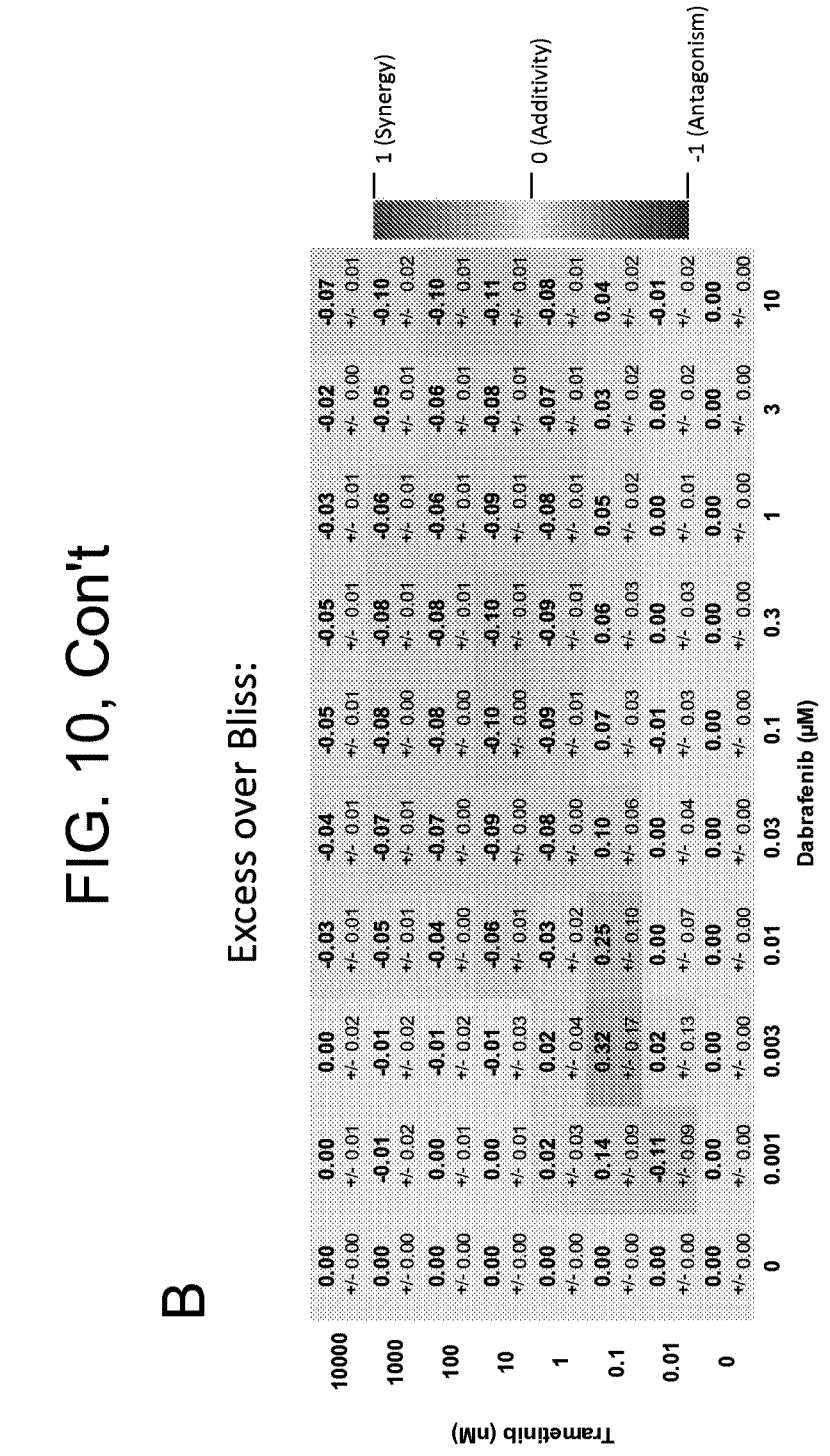


FIG. 10, Con't

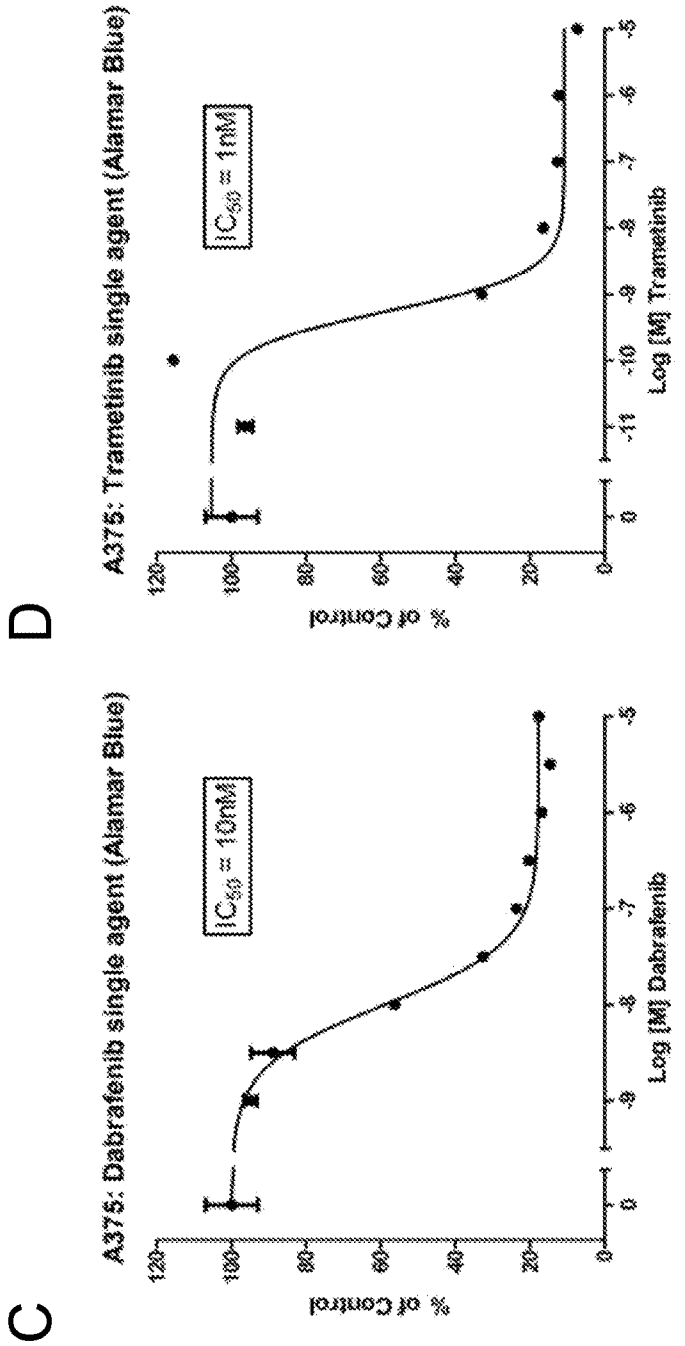

C
A375: Dabrafenib single agent (Alamar Blue)
IC50 = 10nM
% of Control
Log [M] Dabrafenib
D
A375: Trametinib single agent (Alamar Blue)
IC50 = 1nM
% of Control
Log [M] Trametinib

FIG. 10, Con't

E

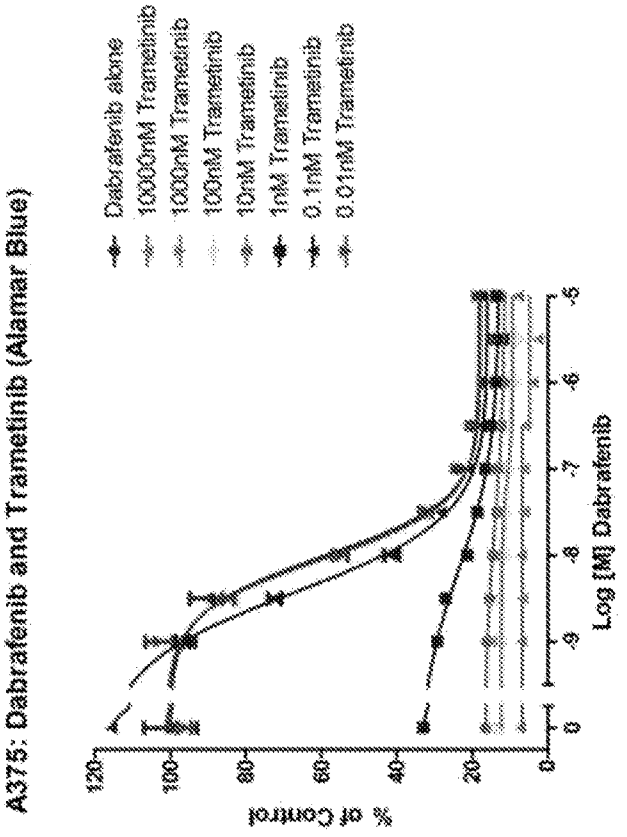

A375: Dabrafenib and Trametinib (Alamar Blue)
Dabrafenib alone
1000nM Trametinib
300nM Trametinib
100nM Trametinib
10nM Trametinib
1nM Trametinib
0.1nM Trametinib
0.01nM Trametinib
% of Control
120
100
80
60
40
20
0
0
-9
-8
-7
-6
-5
Log [M] Dabrafenib

FIG. 11

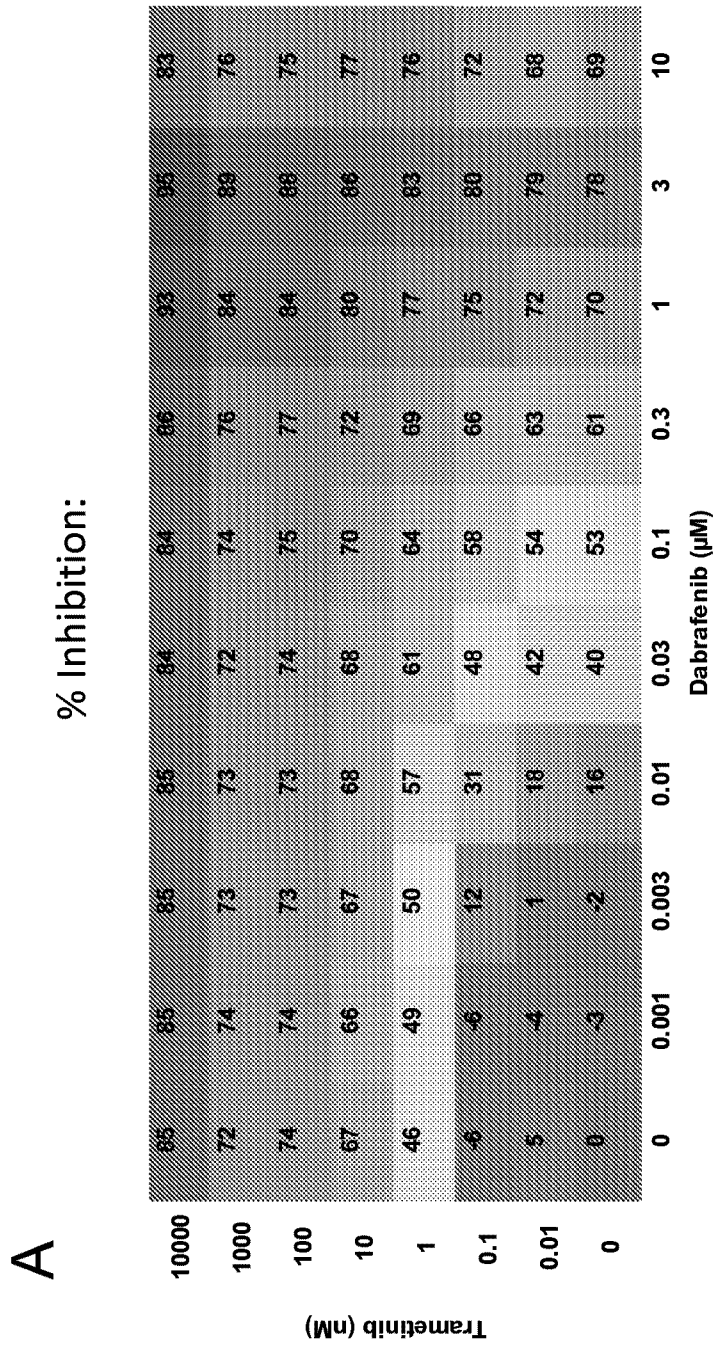

A
% Inhibition:
Trametinib (nM)
10000
1000
100
10
1
0.1
0.01
0
Dabrafenib (μM)
0
0.001
0.003
0.01
0.03
0.1
0.3
1
3
10
85 85 85 85 84 84 86 93 85 83
72 74 73 73 72 74 76 84 89 76
74 74 73 73 74 75 77 84 88 75
67 66 67 68 68 70 72 80 86 77
46 49 50 57 61 64 69 77 83 76
-6 -6 12 31 48 58 66 75 80 72
5 -4 1 18 42 54 63 72 79 68
0 -3 -2 16 40 53 61 70 78 69

FIG. 11, Con't

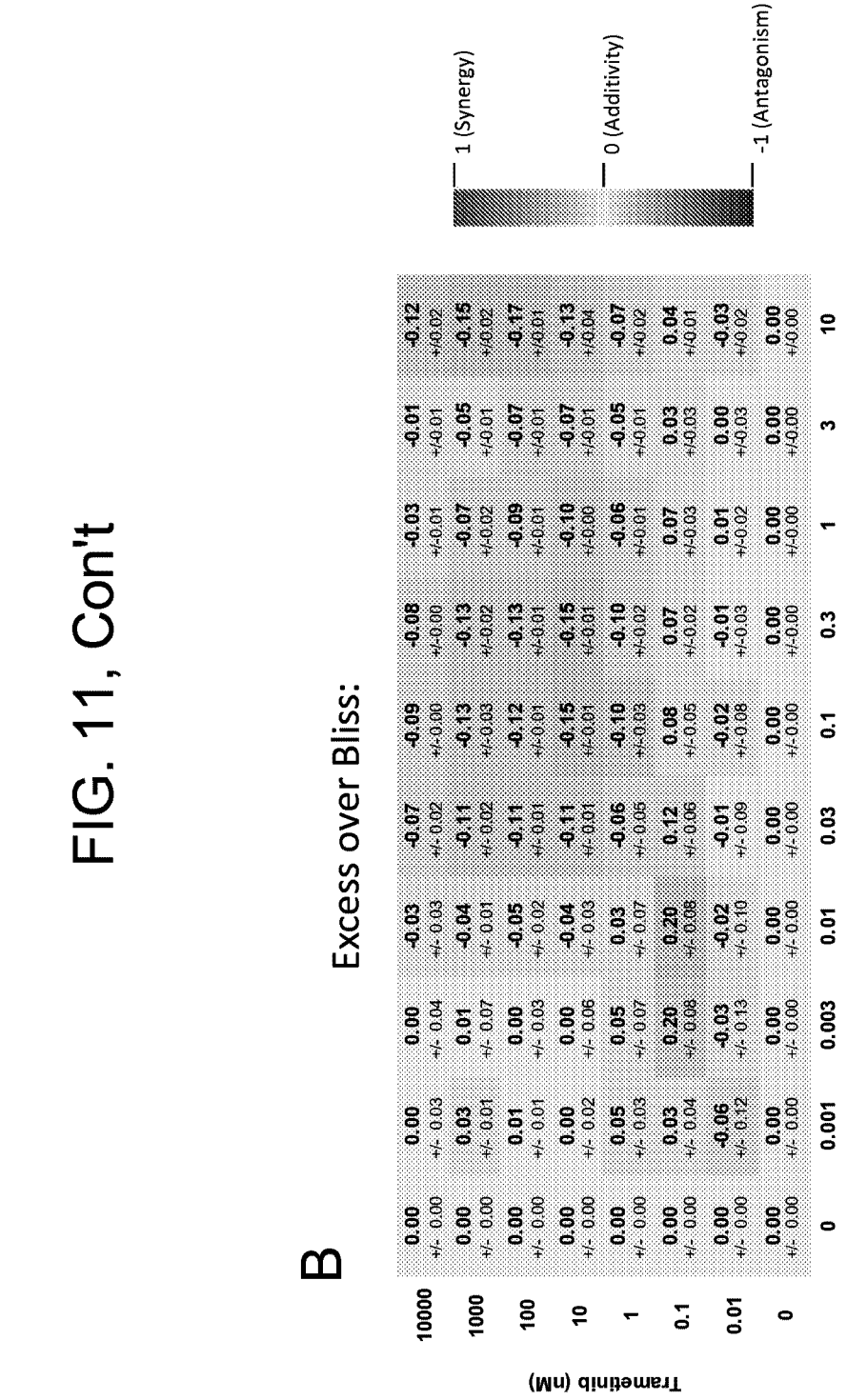

B
Excess over Bliss:
1 (Synergy)
0 (Additivity)
-1 (Antagonism)
Trametinib (nM)
Dabrafenib (μM)
10000
1000
100
10
1
0.1
0.01
0
0
0.001
0.003
0.01
0.03
0.1
0.3
1
3
10
0.00 +/- 0.00 | 0.00 +/- 0.03 | 0.00 +/- 0.04 | -0.03 +/- 0.03 | -0.07 +/- 0.02 | -0.09 +/-0.00 | -0.08 +/-0.00 | -0.03 +/-0.01 | -0.01 +/-0.01 | -0.12 +/-0.02
0.00 +/- 0.00 | 0.03 +/- 0.01 | 0.01 +/- 0.07 | -0.04 +/- 0.01 | -0.11 +/- 0.02 | -0.13 +/-0.03 | -0.13 +/-0.02 | -0.07 +/-0.02 | -0.05 +/-0.01 | -0.15 +/-0.02
0.00 +/- 0.00 | 0.01 +/- 0.01 | 0.00 +/- 0.03 | -0.05 +/- 0.02 | -0.11 +/- 0.01 | -0.12 +/-0.01 | -0.13 +/-0.01 | -0.09 +/-0.01 | -0.07 +/-0.01 | -0.17 +/-0.01
0.00 +/- 0.00 | 0.00 +/- 0.02 | 0.00 +/- 0.06 | -0.04 +/- 0.03 | -0.11 +/-0.01 | -0.15 +/-0.01 | -0.15 +/-0.01 | -0.10 +/-0.00 | -0.07 +/-0.01 | -0.13 +/-0.04
0.00 +/- 0.00 | 0.05 +/- 0.03 | 0.05 +/- 0.07 | 0.03 +/- 0.07 | -0.06 +/-0.05 | -0.10 +/-0.03 | -0.10 +/-0.02 | -0.06 +/-0.01 | -0.05 +/-0.01 | -0.07 +/-0.02
0.00 +/- 0.00 | 0.03 +/- 0.04 | 0.20 +/- 0.08 | 0.20 +/- 0.08 | 0.12 +/-0.06 | 0.08 +/-0.05 | 0.07 +/-0.02 | 0.07 +/-0.03 | 0.03 +/-0.03 | 0.04 +/-0.01
0.00 +/- 0.00 | -0.06 +/- 0.12 | -0.03 +/- 0.13 | -0.02 +/- 0.10 | -0.01 +/- 0.09 | -0.02 +/-0.08 | -0.01 +/-0.03 | 0.01 +/-0.02 | 0.00 +/-0.03 | -0.03 +/-0.02
0.00 +/- 0.00 | 0.00 +/- 0.00 | 0.00 +/- 0.00 | 0.00 +/- 0.00 | 0.00 +/-0.00 | 0.00 +/-0.00 | 0.00 +/-0.00 | 0.00 +/-0.00 | 0.00 +/-0.00 | 0.00 +/-0.00

FIG. 11, Con't

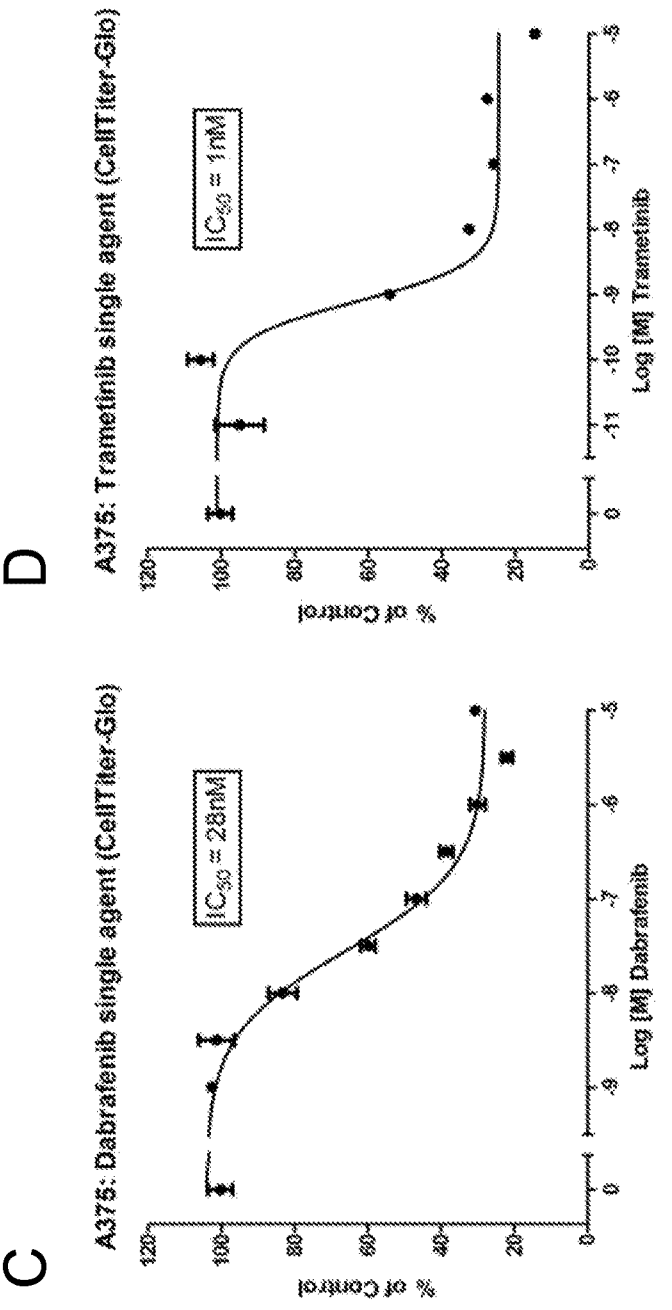

C
A375: Dabrafenib single agent (CellTiter-Glo)
IC50 = 28nM
% of Control
Log [M] Dabrafenib
D
A375: Trametinib single agent (CellTiter-Glo)
IC50 = 1nM
% of Control
Log [M] Trametinib

FIG. 11, Con't

E

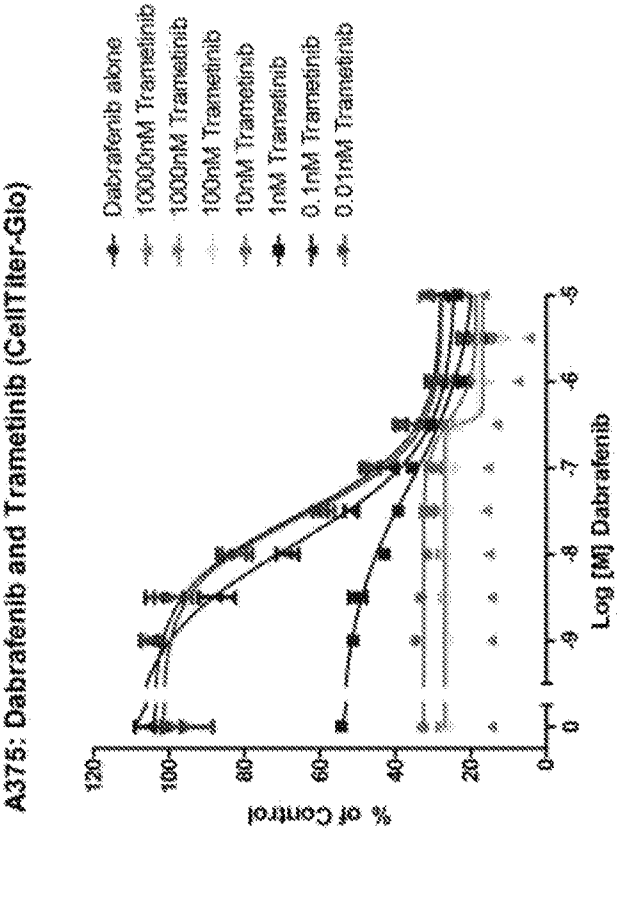

A375; Dabrafenib and Trametinib (CellTiter-Glo)
Dabrafenib alone
10000nM Trametinib
1000nM Trametinib
100nM Trametinib
10nM Trametinib
1nM Trametinib
0.1nM Trametinib
0.01nM Trametinib
% of Control
120
100
80
60
40
20
0
-5
-6
-7
-8
-9
Log [M] Dabrafenib

FIG. 12

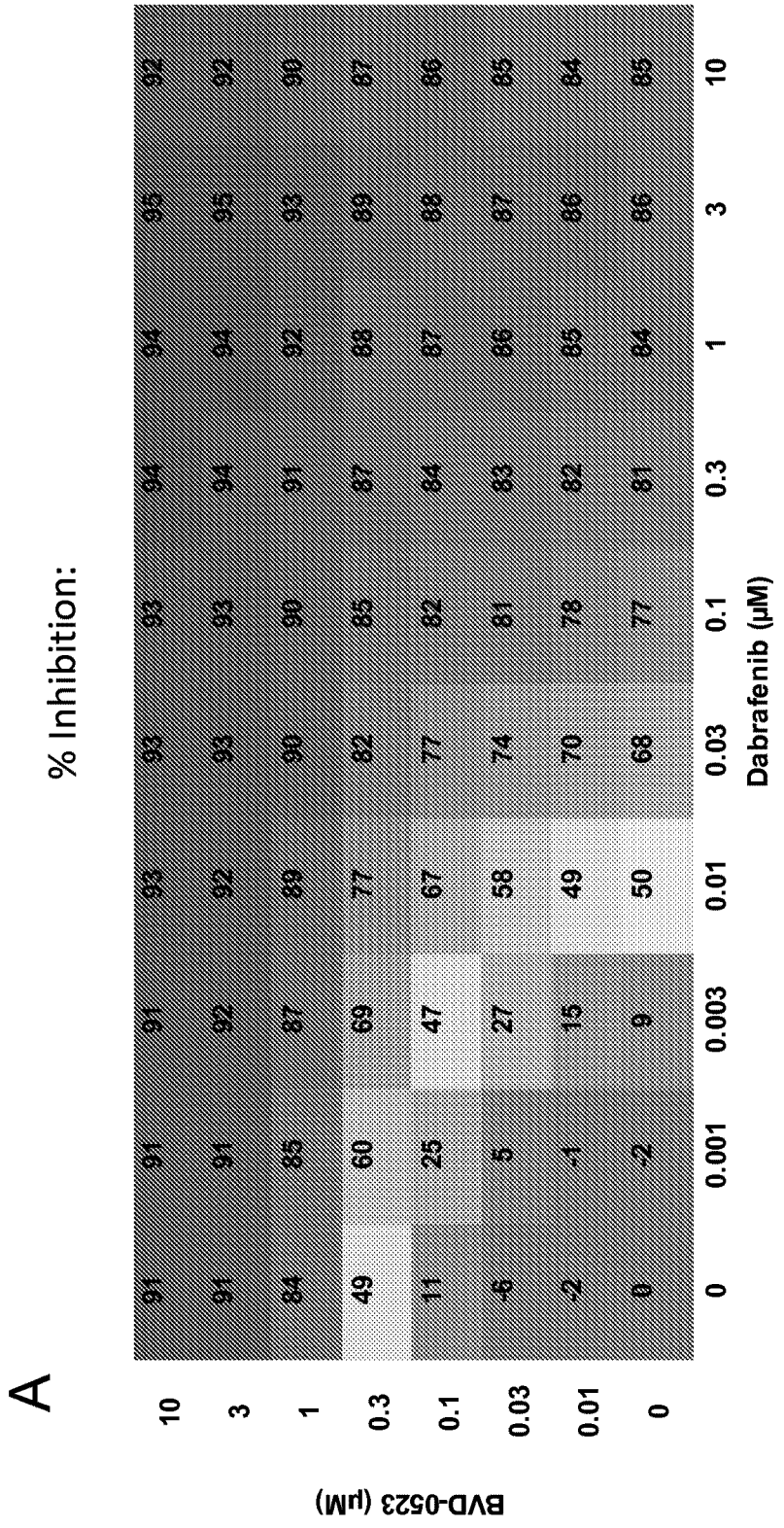

A
% Inhibition:
BVD-0523 (μM)
10
3
1
0.3
0.1
0.03
0.01
0
0
0.001
0.003
0.01
0.03
0.1
0.3
1
3
10
Dabrafenib (μM)
91 91 91 93 93 93 94 94 95 92
91 91 92 92 93 93 94 94 95 92
84 85 87 89 90 90 91 92 93 90
49 60 69 77 82 85 87 88 89 87
11 25 47 67 77 82 84 87 88 86
-6 5 27 58 74 81 83 86 87 85
-2 -1 15 49 70 78 82 85 86 84
0 -2 9 50 68 77 81 84 86 85

FIG. 12, Con't

B

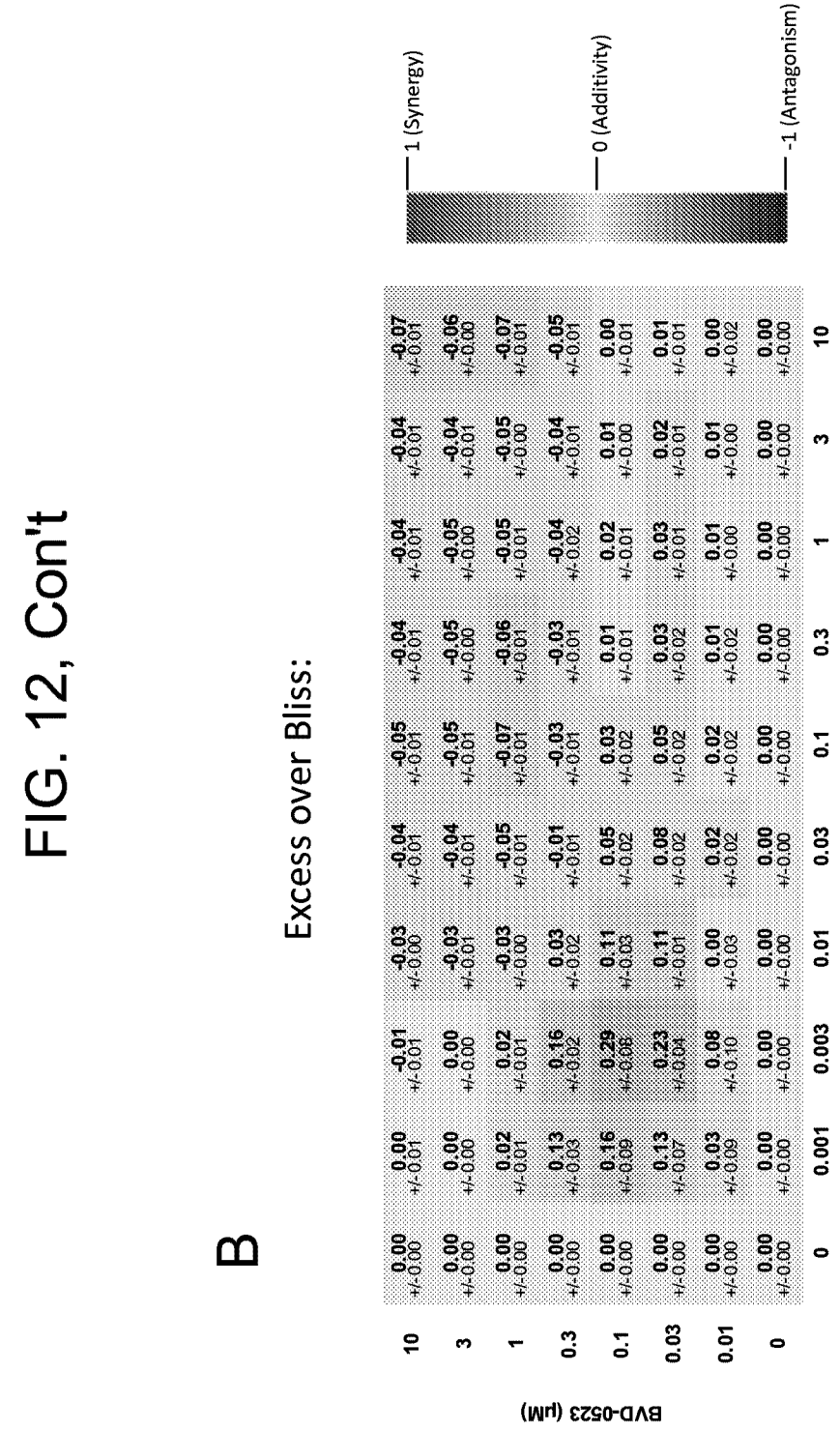

Excess over Bliss:
1 (Synergy)
0 (Additivity)
-1 (Antagonism)
BVD-0523 (μM)
Dabrafenib (μM)
10 3 1 0.3 0.1 0.03 0.01 0
0 0.001 0.003 0.01 0.03 0.1 0.3 1 3 10

FIG. 12, Con't

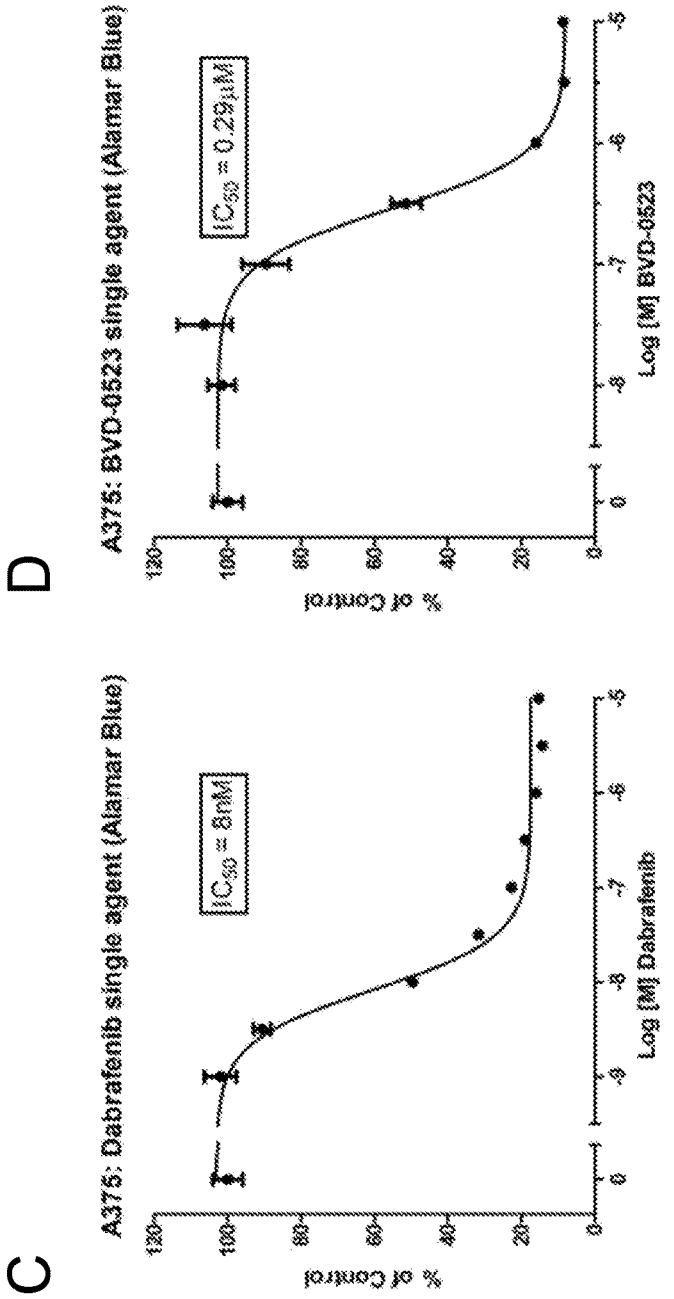

C
A375: Dabrafenib single agent (Alamar Blue)
IC50 = 8nM
% of Control
Log [M] Dabrafenib
D
A375: BVD-0523 single agent (Alamar Blue)
IC50 = 0.29μM
% of Control
Log [M] BVD-0523

FIG. 12, Con't

E

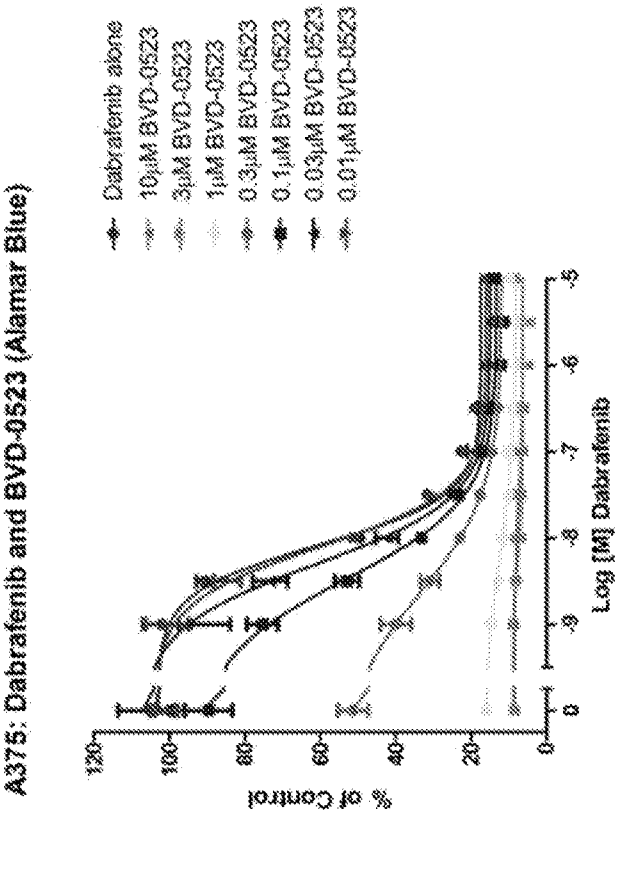

A375: Dabrafenib and BVD-0523 (Alamar Blue)
Dabrafenib alone
10μM BVD-0523
3μM BVD-0523
1μM BVD-0523
0.3μM BVD-0523
0.1μM BVD-0523
0.03μM BVD-0523
0.01μM BVD-0523
% of Control
120
100
80
60
40
20
0
0
-9
-8
-7
-6
-5
Log [M] Dabrafenib

FIG. 13

A

% Inhibition:

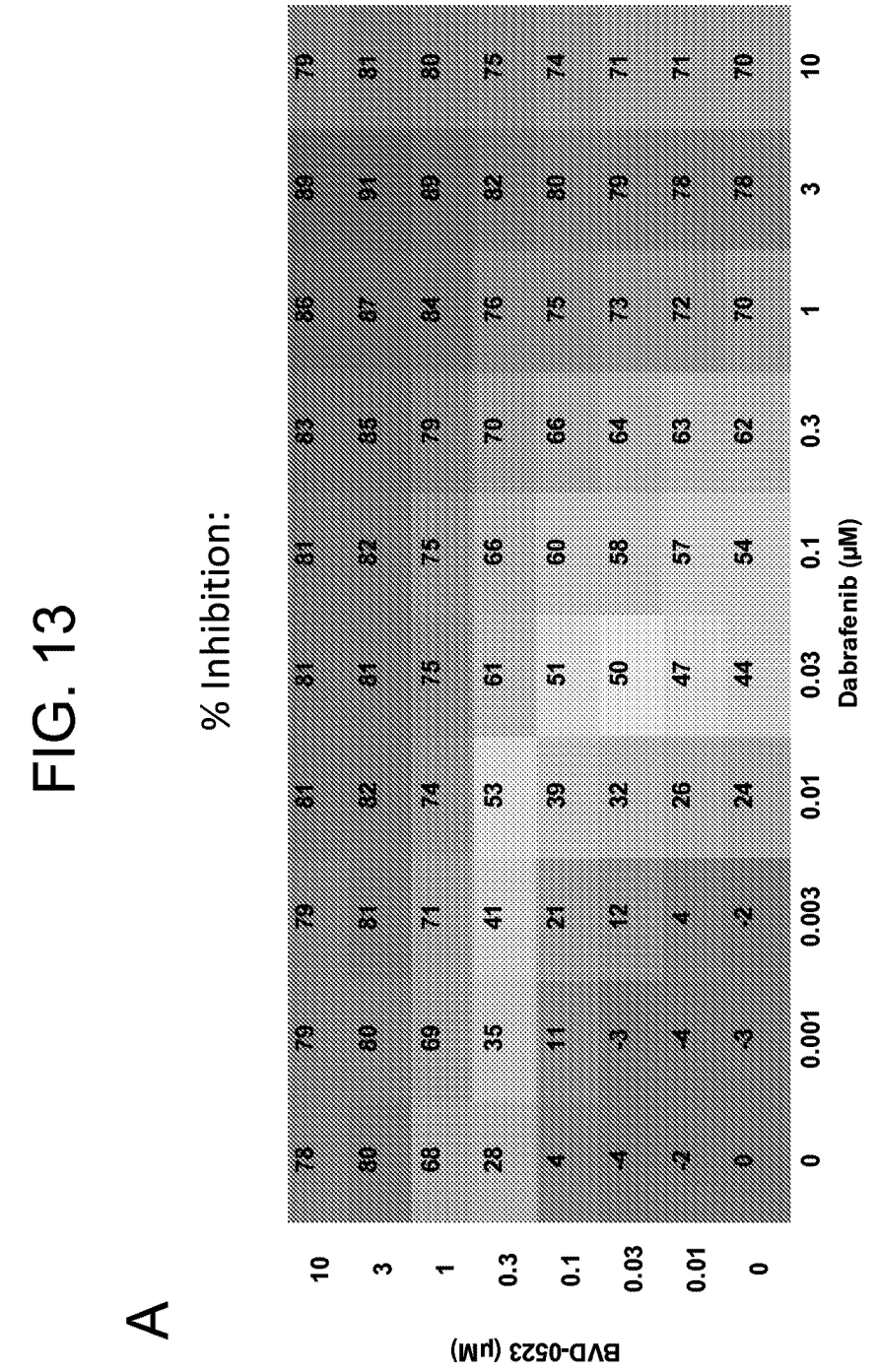


FIG. 13, Con't

B

Excess over Bliss:

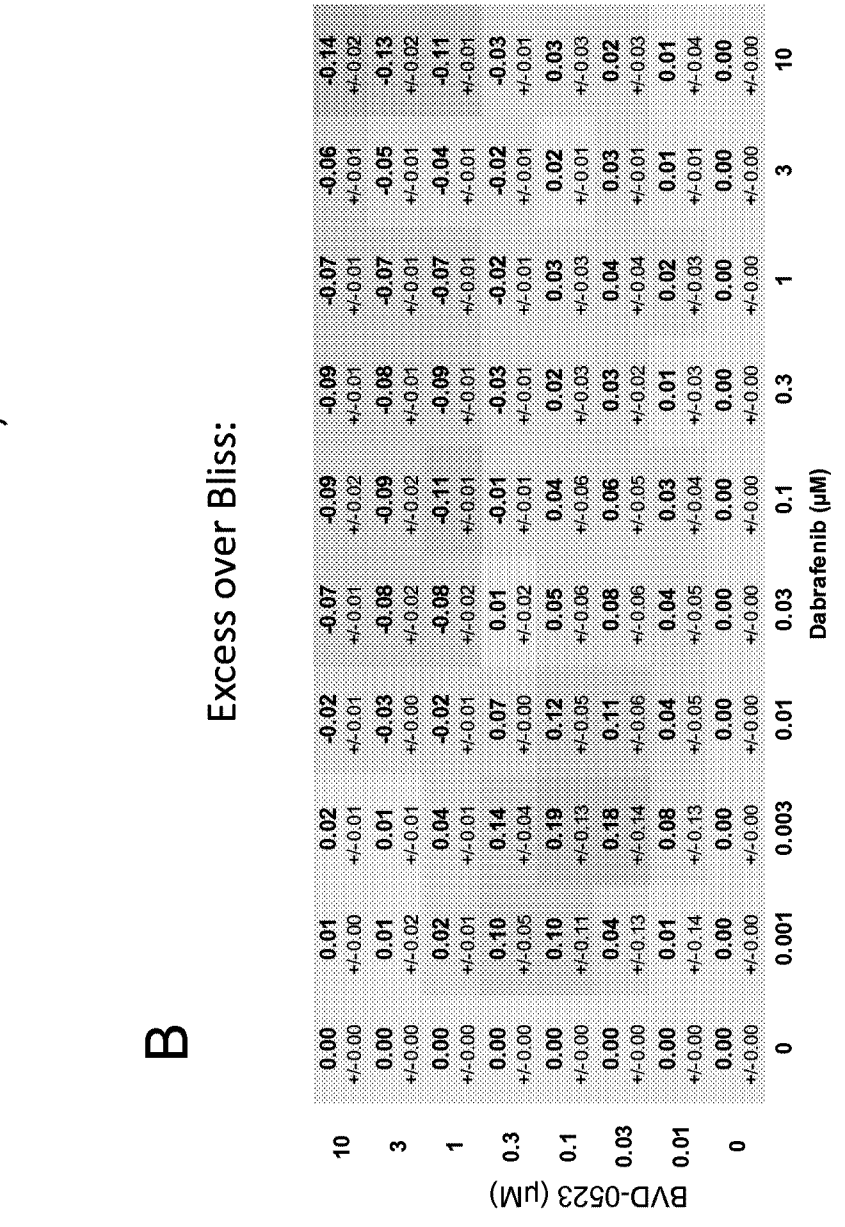


FIG. 13, Con't

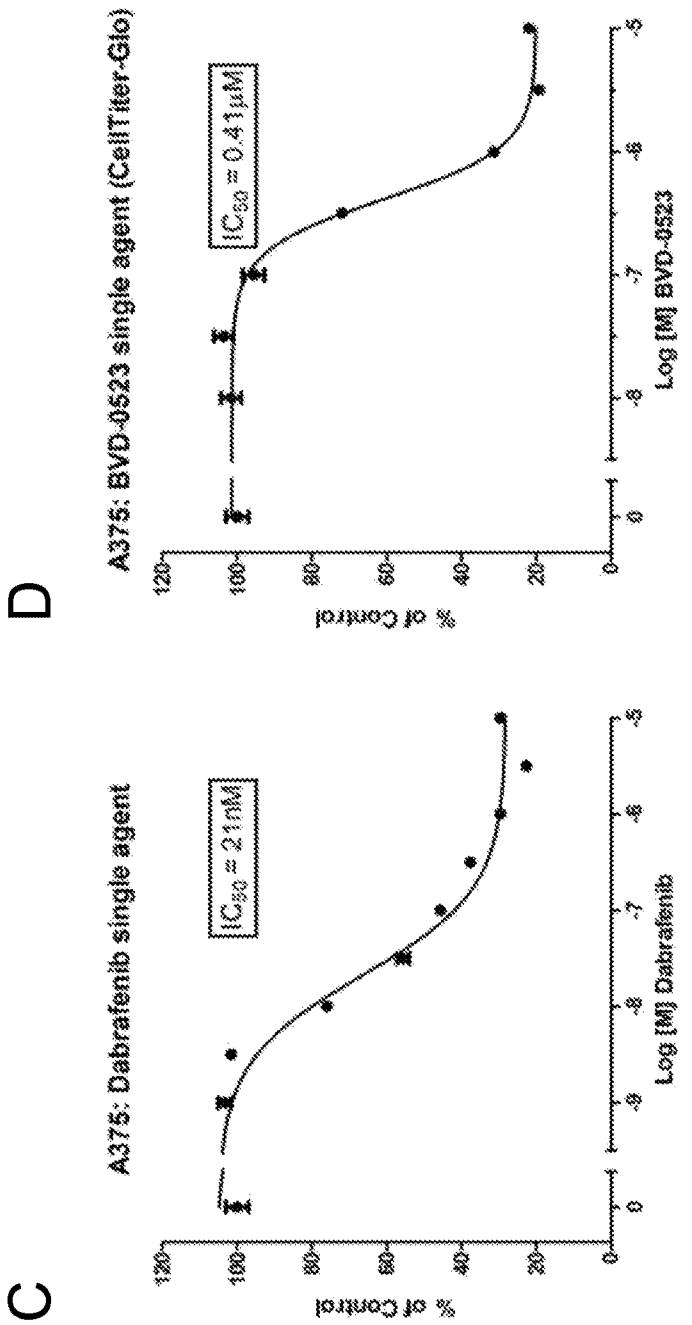

C
A375: Dabrafenib single agent
IC50 = 21nM
% of Control
Log [M] Dabrafenib
D
A375: BVD-0523 single agent (CellTiter-Glo)
IC50 = 0.41μM
% of Control
Log [M] BVD-0523

FIG. 13, Con't

E

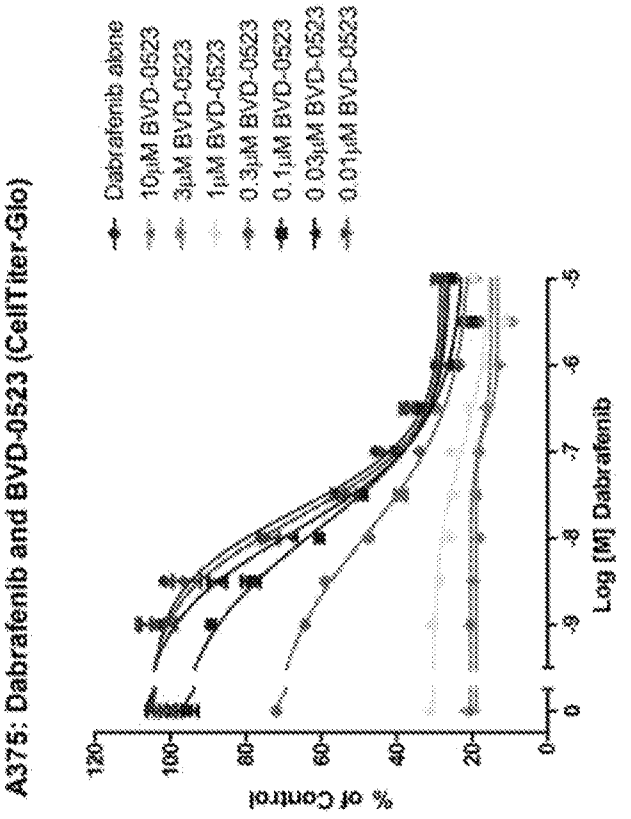

A375: Dabrafenib and BVD-0523 (CellTiter-Glo)
Dabrafenib alone
10μM BVD-0523
3μM BVD-0523
1μM BVD-0523
0.3μM BVD-0523
0.1μM BVD-0523
0.03μM BVD-0523
0.01μM BVD-0523
% of Control
120
100
80
60
40
20
0
0
-9
-8
-7
-6
-5
Log [M] Dabrafenib

FIG. 14

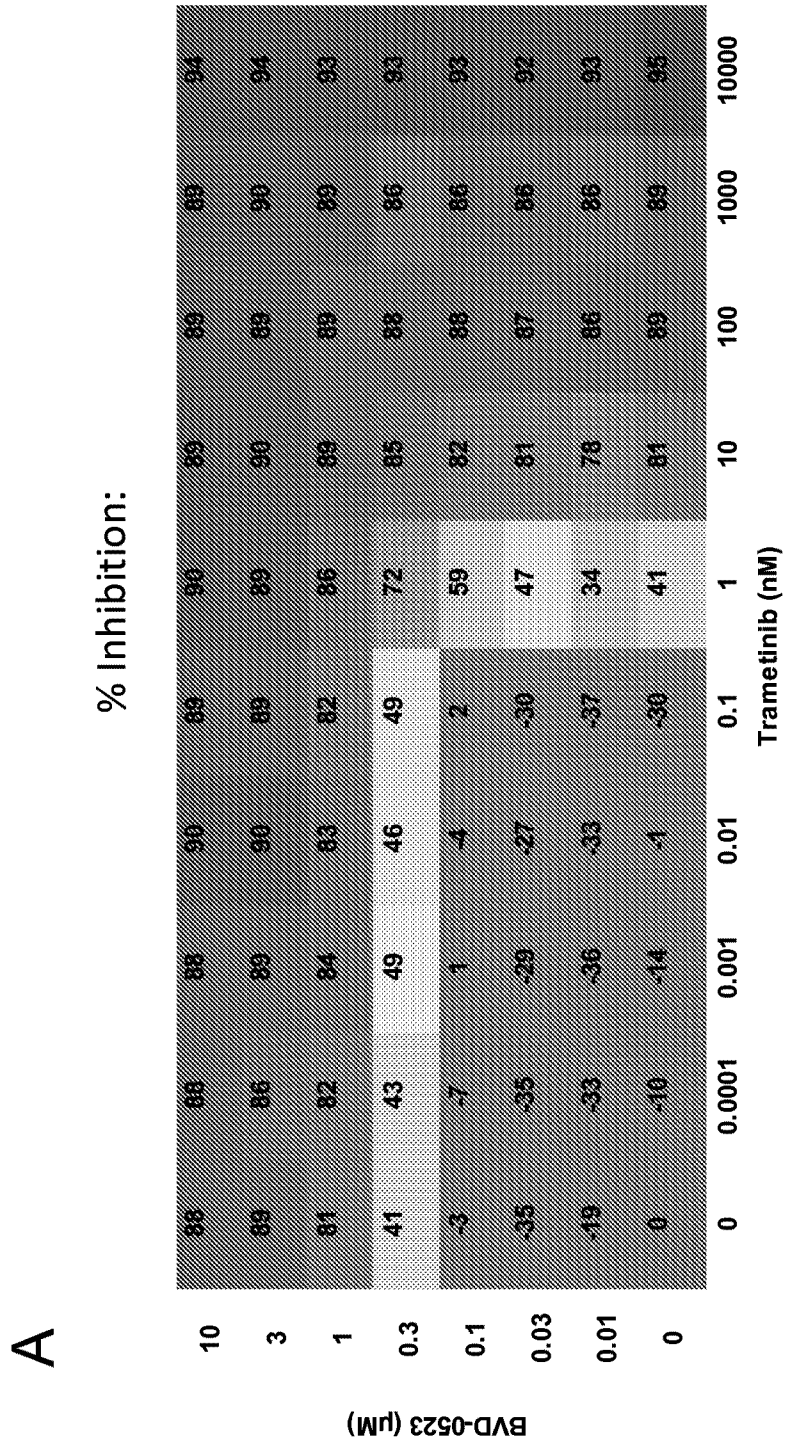

A
% Inhibition:
BVD-523 (μM)
10
3
1
0.3
0.1
0.03
0.01
0
0 0.0001 0.001 0.01 0.1 1 10 100 1000 10000
Trametinib (nM)
88 88 88 90 89 90 89 89 89 94
89 86 89 90 89 90 90 89 90 94
81 82 84 83 82 86 89 89 90 93
41 43 49 46 49 72 85 88 86 93
-3 -7 1 -4 2 59 82 86 86 93
-35 -35 -29 -27 -30 47 81 87 85 92
-19 -33 -36 -33 -37 34 78 86 86 93
0 -10 -14 -1 -30 41 81 89 89 95

FIG. 14, Con't

B

Excess over Bliss:

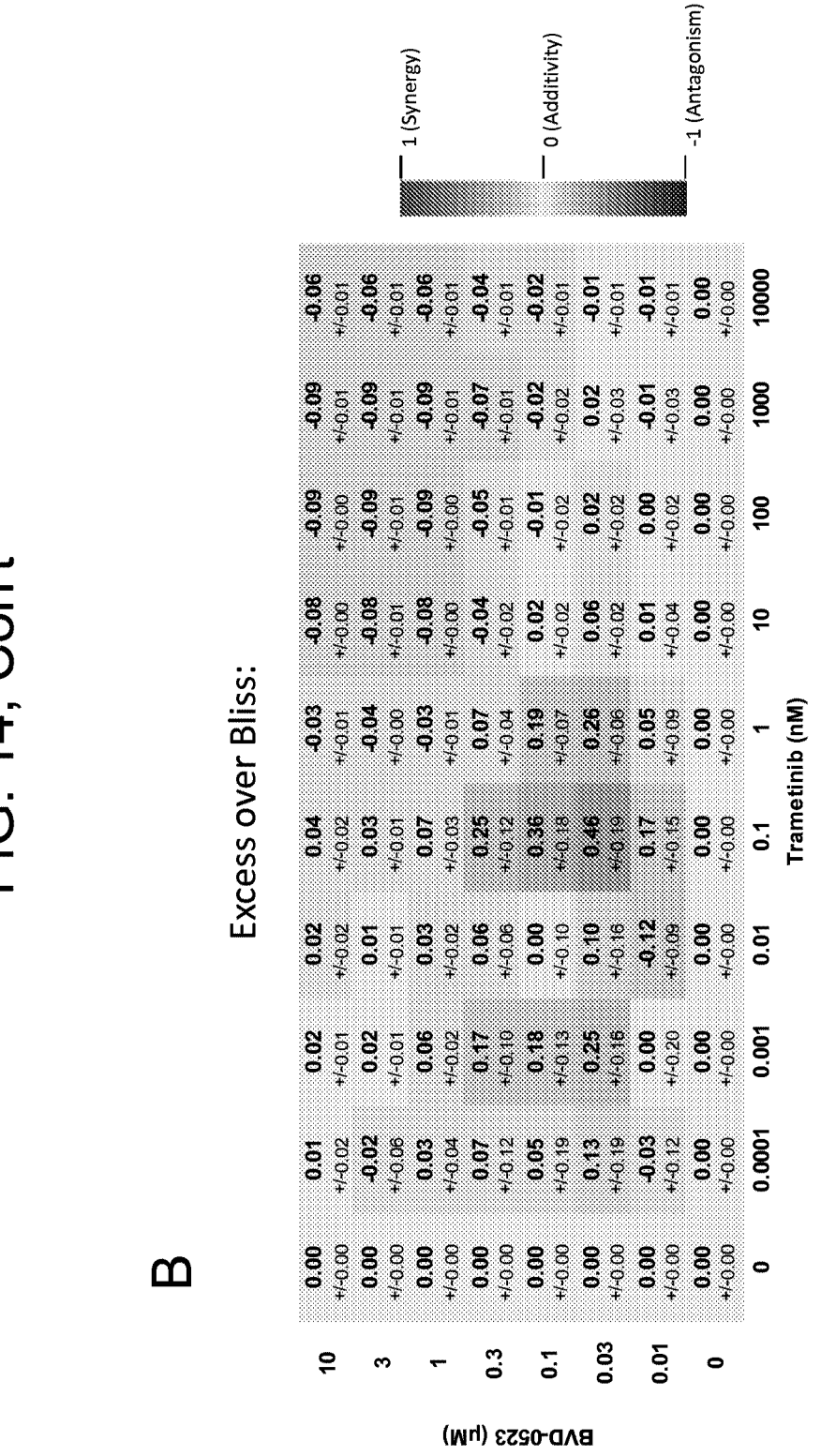


FIG. 14, Con't

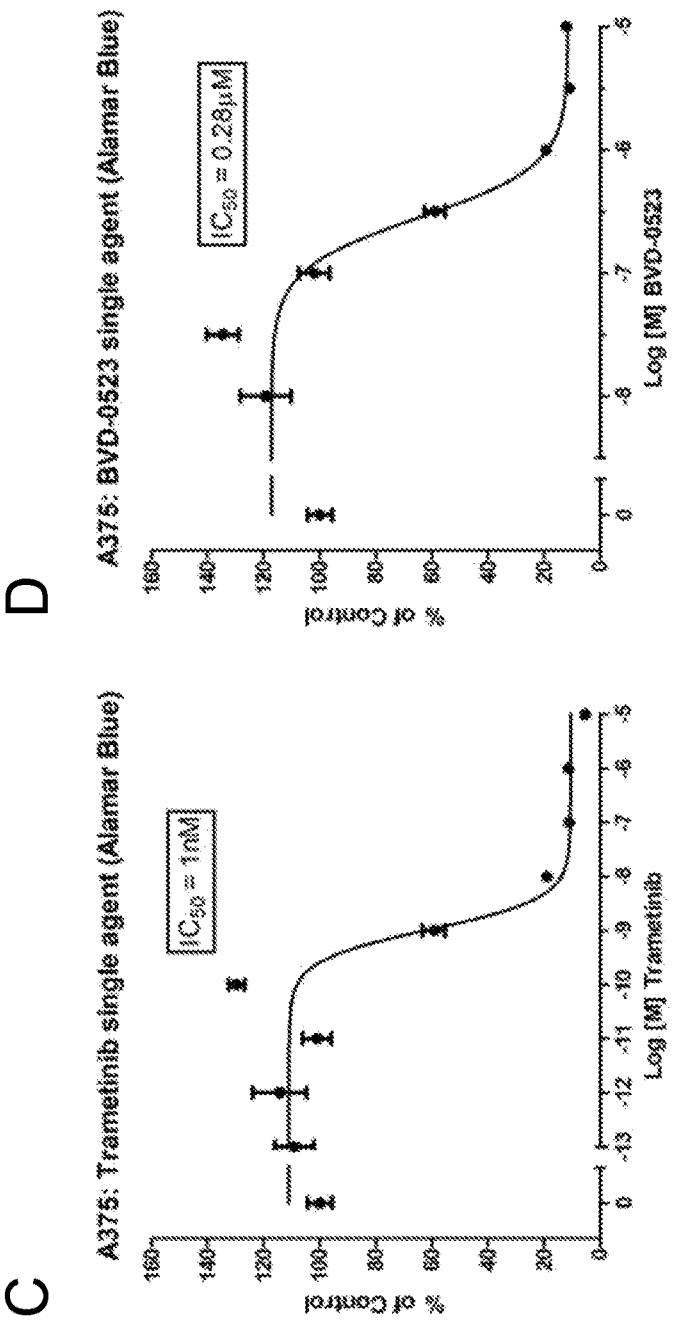

C
A375: Trametinib single agent (Alamar Blue)
IC50 = 1nM
% of Control
Log [M] Trametinib
D
A375: BVD-0523 single agent (Alamar Blue)
IC50 = 0.28μM
% of Control
Log [M] BVD-0523

FIG. 14, Con't

E

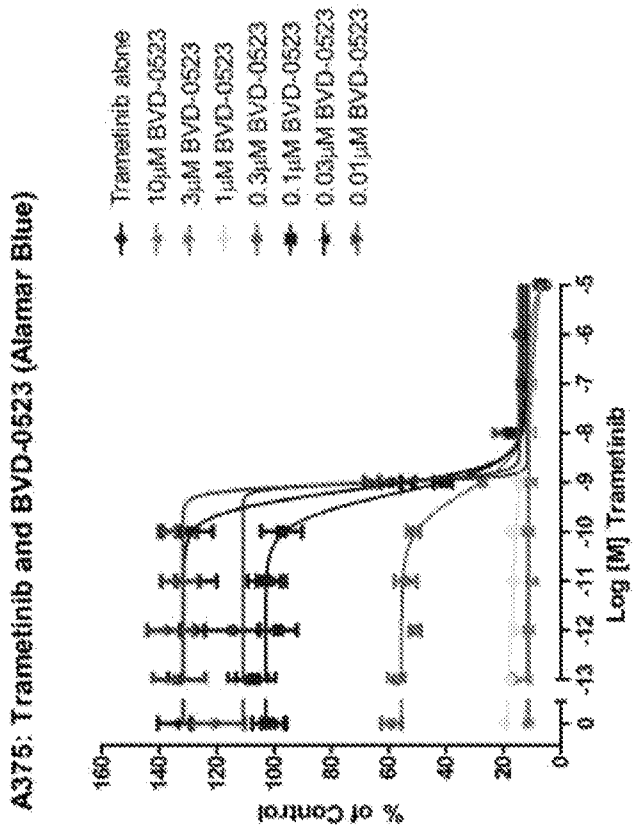

A375: Trametinib and BVD-0523 (Alamar Blue)
Trametinib alone
10μM BVD-0523
3μM BVD-0523
1μM BVD-0523
0.3μM BVD-0523
0.1μM BVD-0523
0.03μM BVD-0523
0.01μM BVD-0523
% of Control
160
140
120
100
80
60
40
20
0
0
-13
-12
-11
-10
-9
-8
-7
-6
-5
Log [M] Trametinib

FIG. 15

A

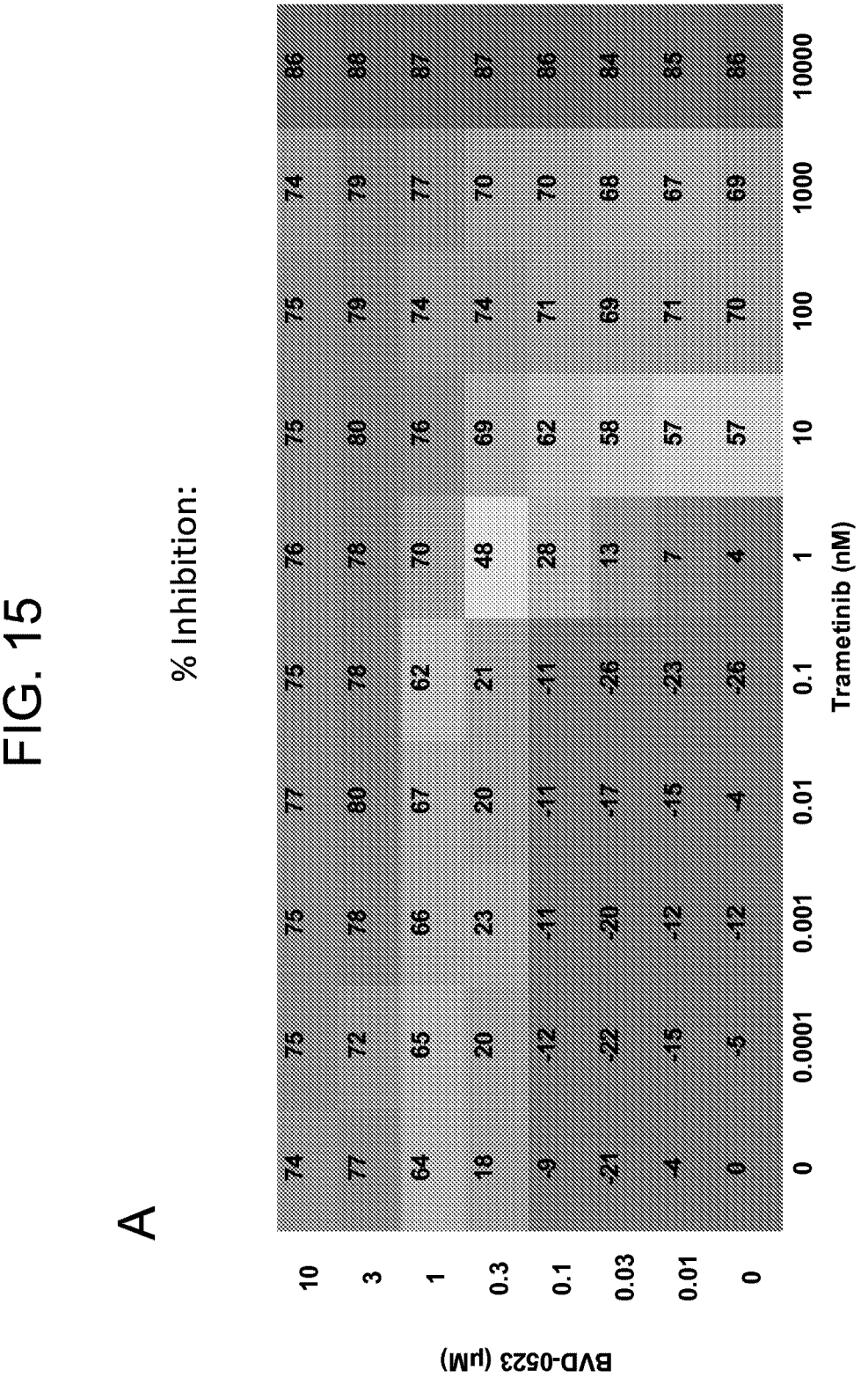

% Inhibition:
BVD-523 (μM)
10
3
1
0.3
0.1
0.03
0.01
0
0 0.0001 0.001 0.01 0.1 1 10 100 1000 10000
Trametinib (nM)
74 75 75 77 75 76 75 75 74 86
77 72 78 80 78 78 80 79 79 88
64 65 66 67 62 70 76 74 77 87
18 20 23 20 21 48 69 74 70 87
-9 -12 -11 -11 -11 28 62 71 70 86
-21 -22 -20 -17 -26 13 58 69 68 84
-4 -15 -12 -15 -23 7 57 71 67 85
0 -5 -12 -4 -26 4 57 70 69 86

FIG. 15, Con't

B

Excess over Bliss:

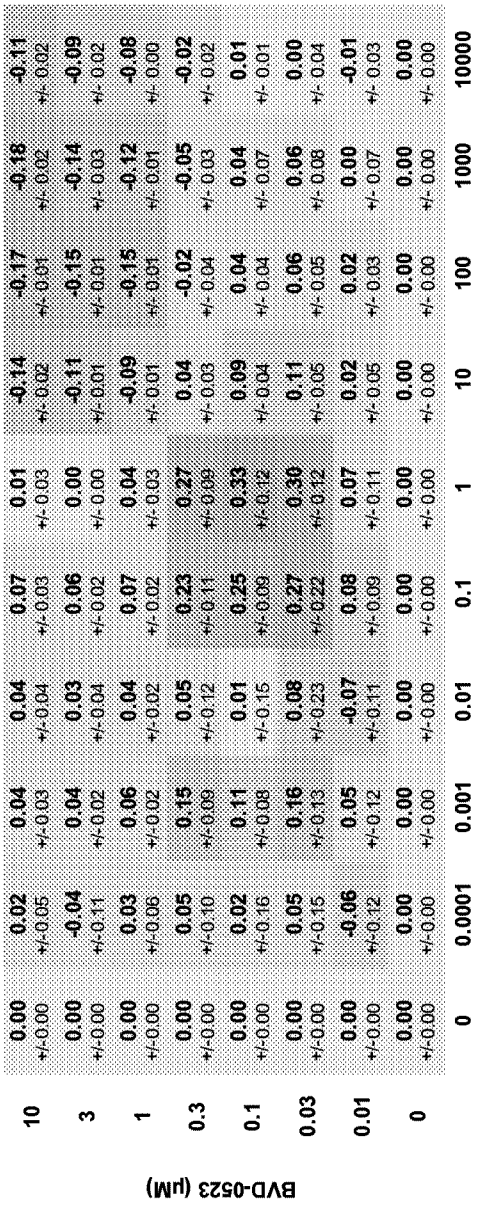


FIG. 15, Con't

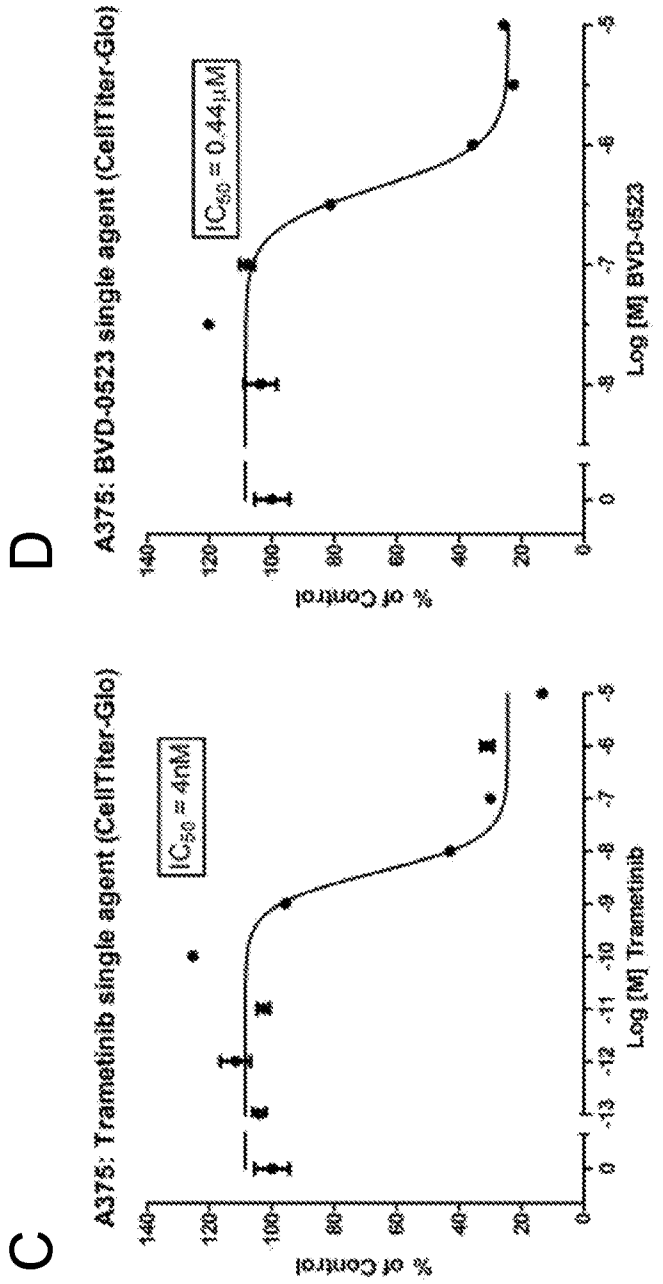

C
A375: Trametinib single agent (CellTiter-Glo)
IC50 = 4nM
% of Control
Log [M] Trametinib
D
A375: BVD-0523 single agent (CellTiter-Glo)
IC50 = 0.44μM
% of Control
Log [M] BVD-0523

FIG. 15, Con't

E

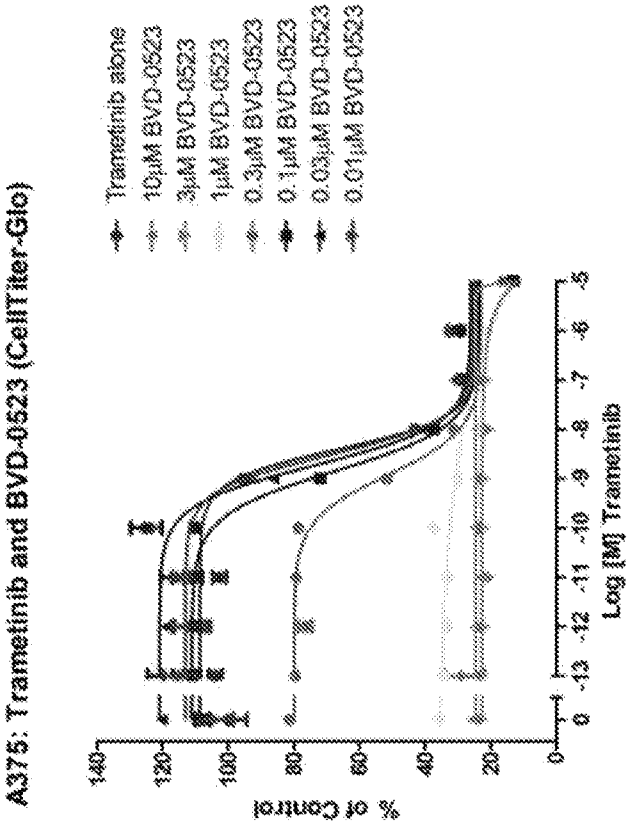

A375: Trametinib and BVD-0523 (CellTiter-Glo)
Trametinib alone
10μM BVD-0523
3μM BVD-0523
1μM BVD-0523
0.3μM BVD-0523
0.1μM BVD-0523
0.03μM BVD-0523
0.01μM BVD-0523
% of Control
140
120
100
80
60
40
20
0
0
-13
-12
-11
-10
-9
-8
-7
-6
-5
Log [M] Trametinib

FIG. 16

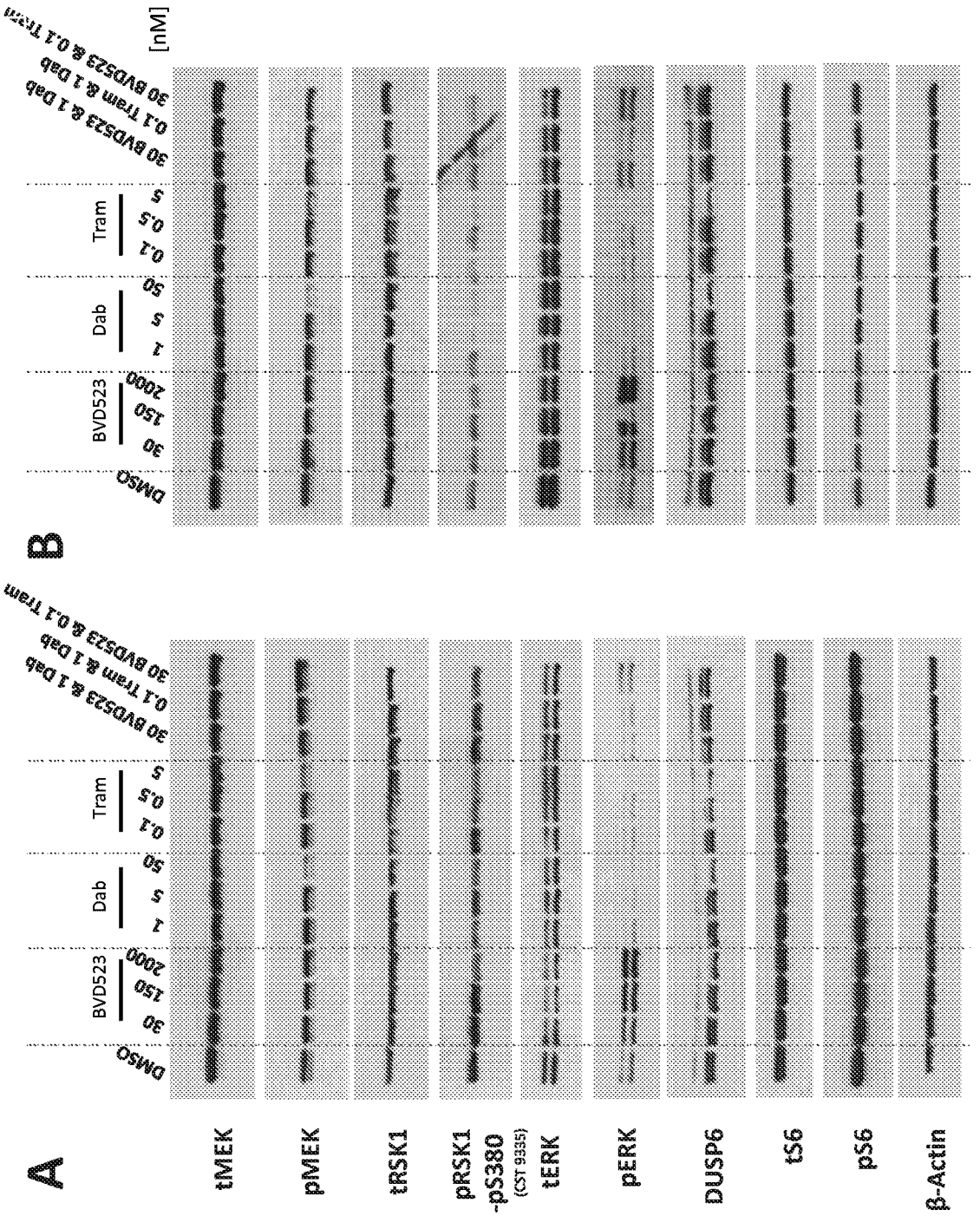

A
B
DMSO
BVD523
30
150
2000
Dab
1
5
50
Tram
0.1
0.5
5
30 BVD523 & 1 Dab
0.1 Tram & 1 Dab
30 BVD523 & 0.1 Tram
[nM]
tMEK
pMEK
tRSK1
pRSK1 -pS380 (CST 9335)
tERK
pERK
DUSP6
tS6
pS6
β-Actin

FIG. 16 Con't

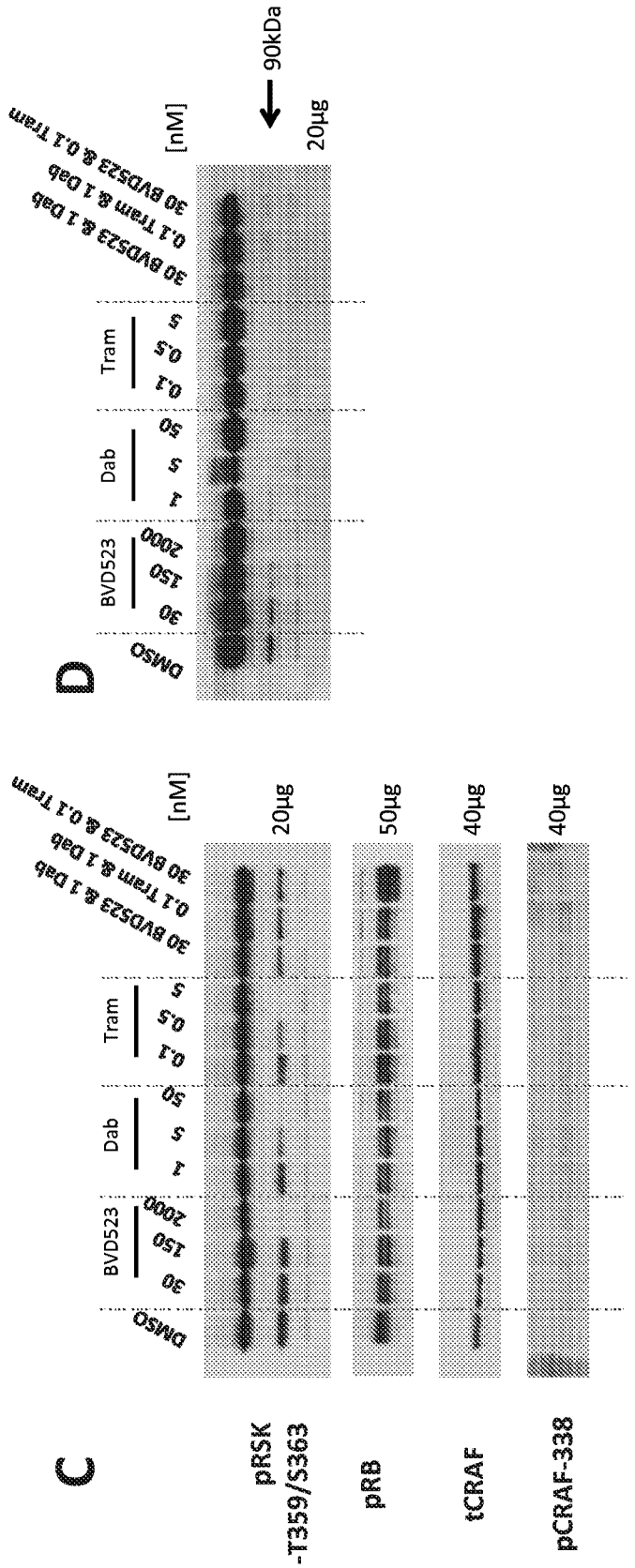

C
pRSK -T359/S363
pRB
tCRAF
pCRAF-338
20µg
50µg
40µg
40µg
[nM]
DMSO
BVD523 30 150 2000
Dab 1 5 50
Tram 0.1 0.5 5
30 BVD523 & 1 Dab
0.1 Tram & 1 Dab
30 BVD523 & 0.1 Tram
D
90kDa
20µg
[nM]
DMSO
BVD523 30 150 2000
Dab 1 5 50
Tram 0.1 0.5 5
30 BVD523 & 1 Dab
0.1 Tram & 1 Dab
30 BVD523 & 0.1 Tram

FIG. 17

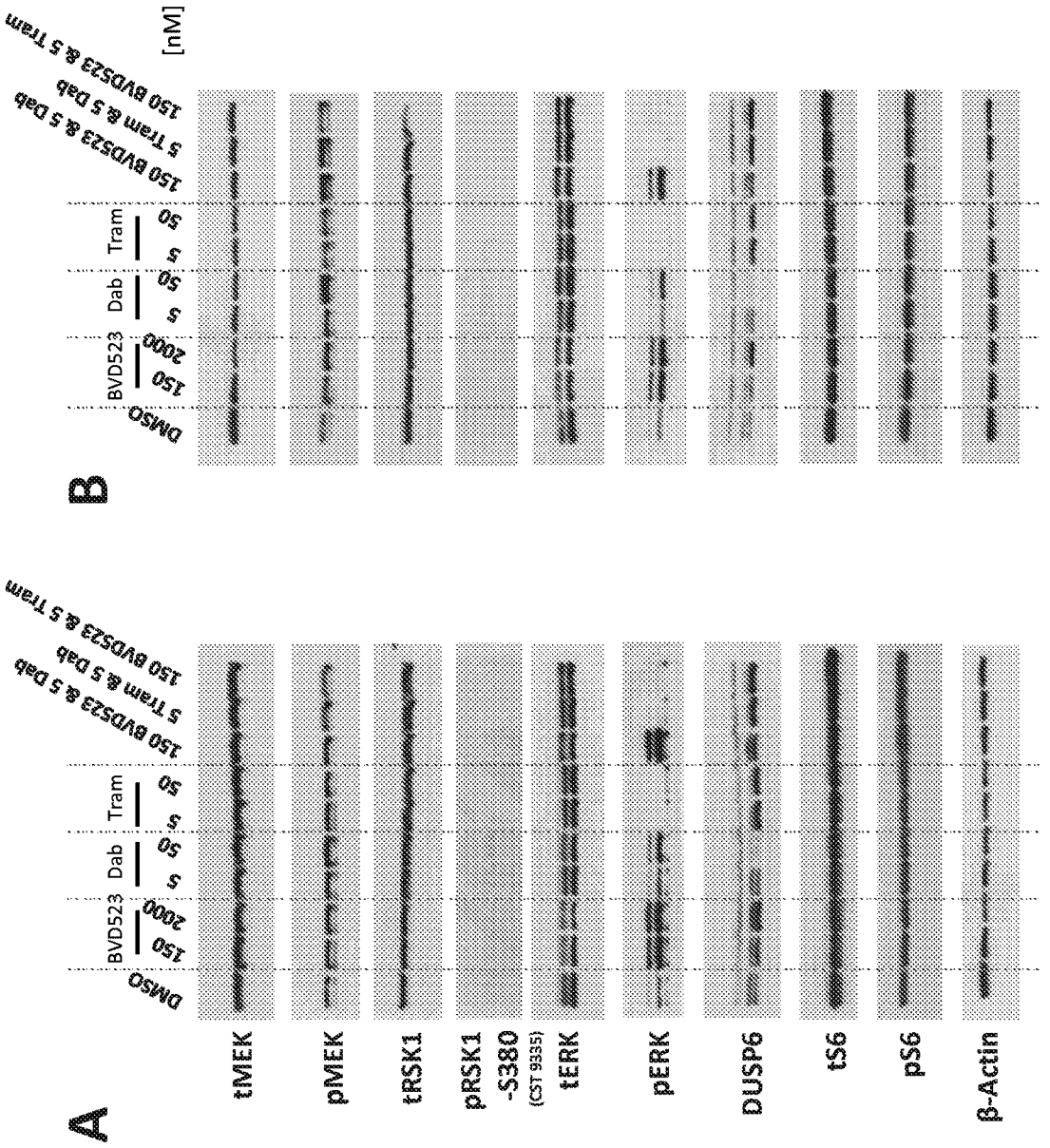

A
B
[nM]
DMSO
BVD523
150
2000
Dab
50
5
Tram
50
5
150 BVD523 & 5 Dab
5 Tram & 5 Dab
150 BVD523 & 5 Tram
tMEK
pMEK
tRSK1
pRSK1 -S380 (CST 9335)
tERK
pERK
DUSP6
tS6
pS6
β-Actin

FIG. 17 Con't

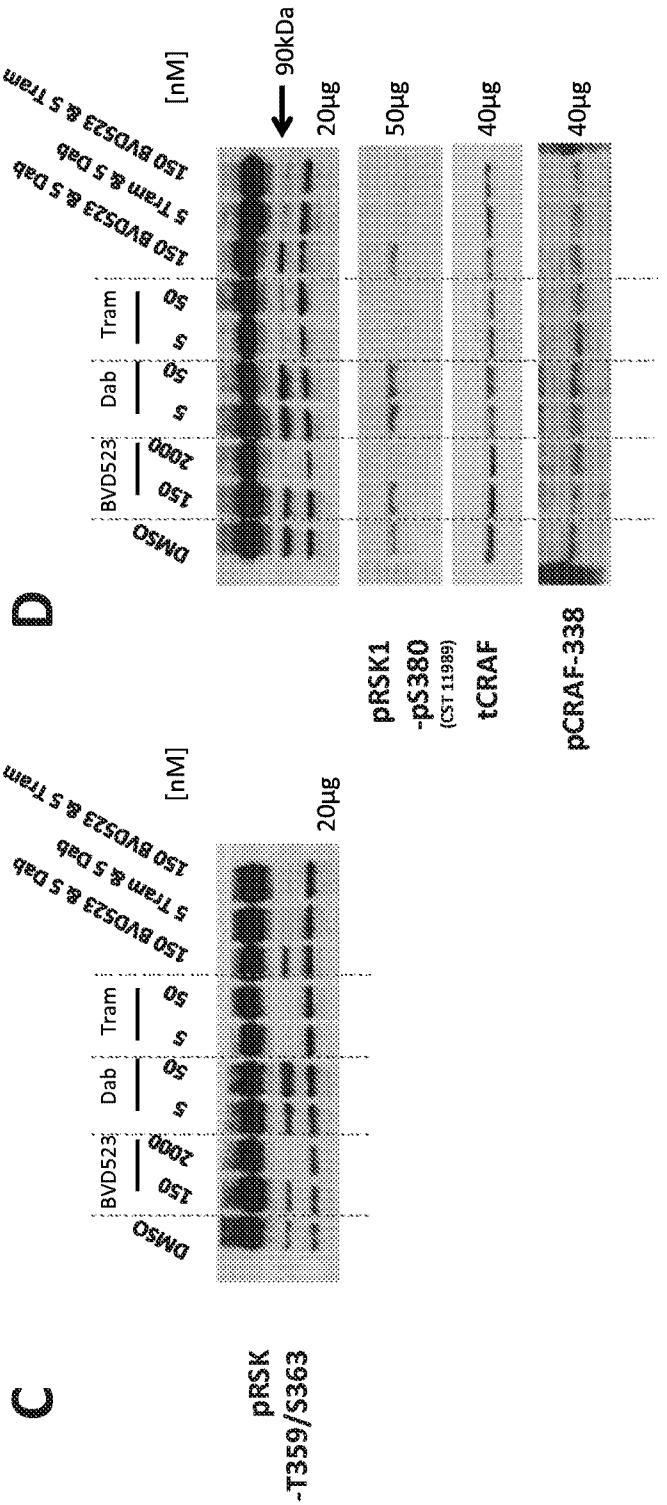

C
pRSK
-T359/S363
20µg
[nM]
150 BVD523 & 5 Tram
5 Tram & 5 Dab
150 BVD523 & 5 Dab
DMSO
BVD523
150
2000
Dab
5
50
Tram
5
50
D
90kDa
20µg
50µg
40µg
40µg
pRSK1
-pS380
(CST 11989)
tCRAF
pCRAF-338

FIG. 18

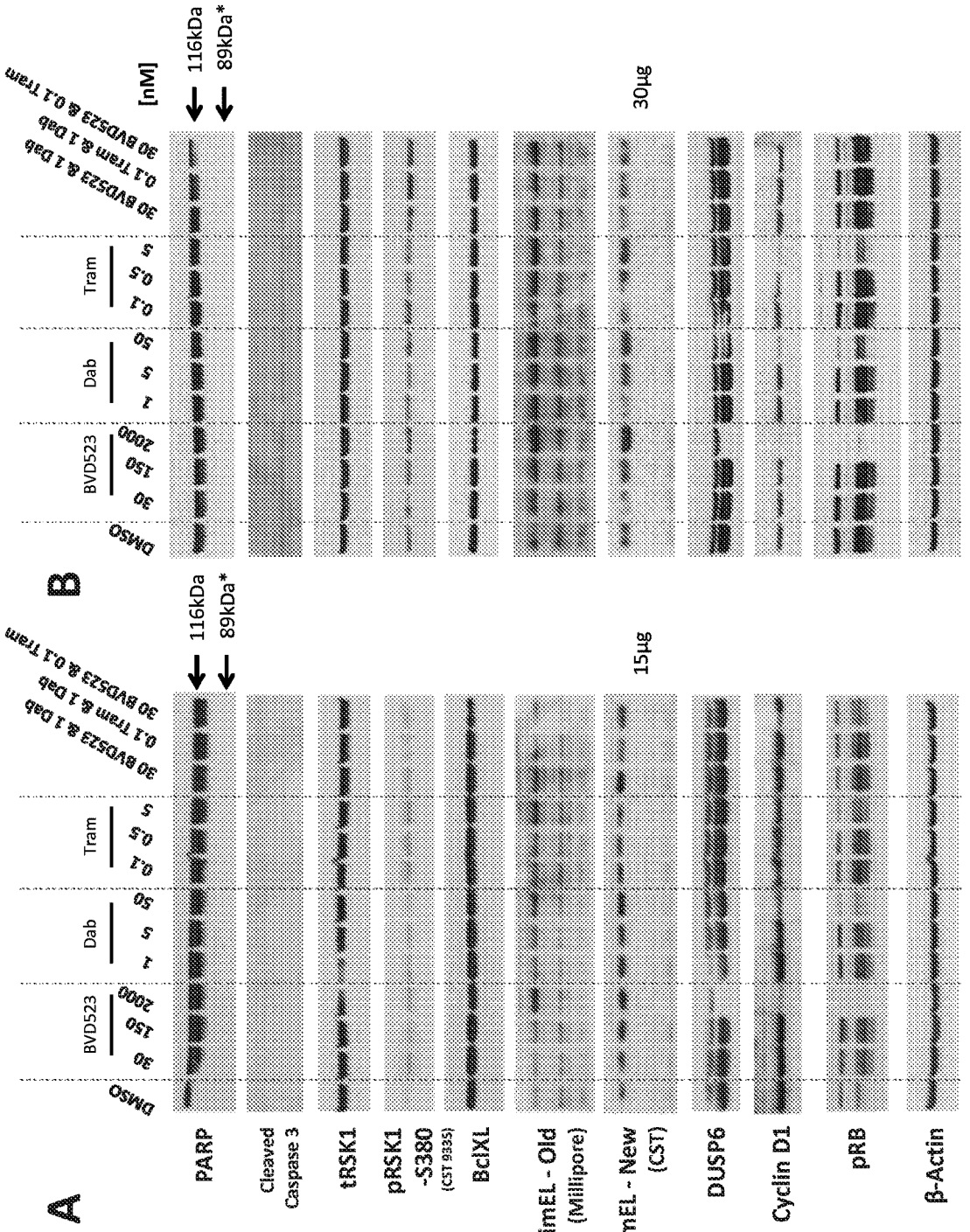

A
B
DMSO
BVD523
30
150
2000
Dab
1
5
50
Tram
0.1
0.5
5
30 BVD523 & 1 Dab
0.1 Tram & 1 Dab
30 BVD523 & 0.1 Tram
[nM]
116kDa
89kDa*
15µg
30µg
PARP
Cleaved Caspase 3
tRSK1
pRSK1 -S380 (CST 9335)
BclXL
BimEL - Old (Millipore)
BimEL - New (CST)
DUSP6
Cyclin D1
pRB
β-Actin

FIG. 18 Con't

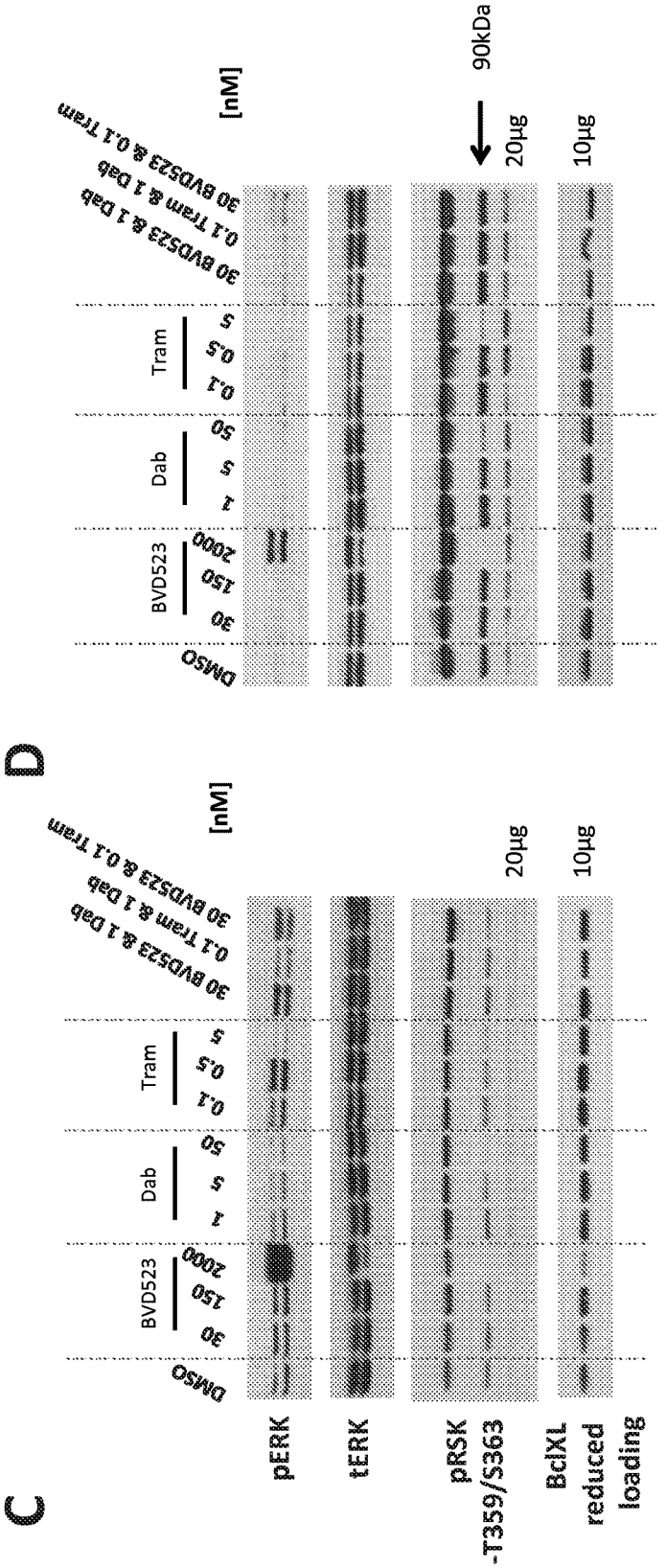

C
D
[nM]
DMSO
30
150
2000
BVD523
1
5
50
Dab
0.1
0.5
5
Tram
30 BVD523 & 1 Dab
0.1 Tram & 1 Dab
30 BVD523 & 0.1 Tram
20µg
10µg
90kDa
pERK
tERK
pRSK -T359/S363
BclXL reduced loading

FIG. 19

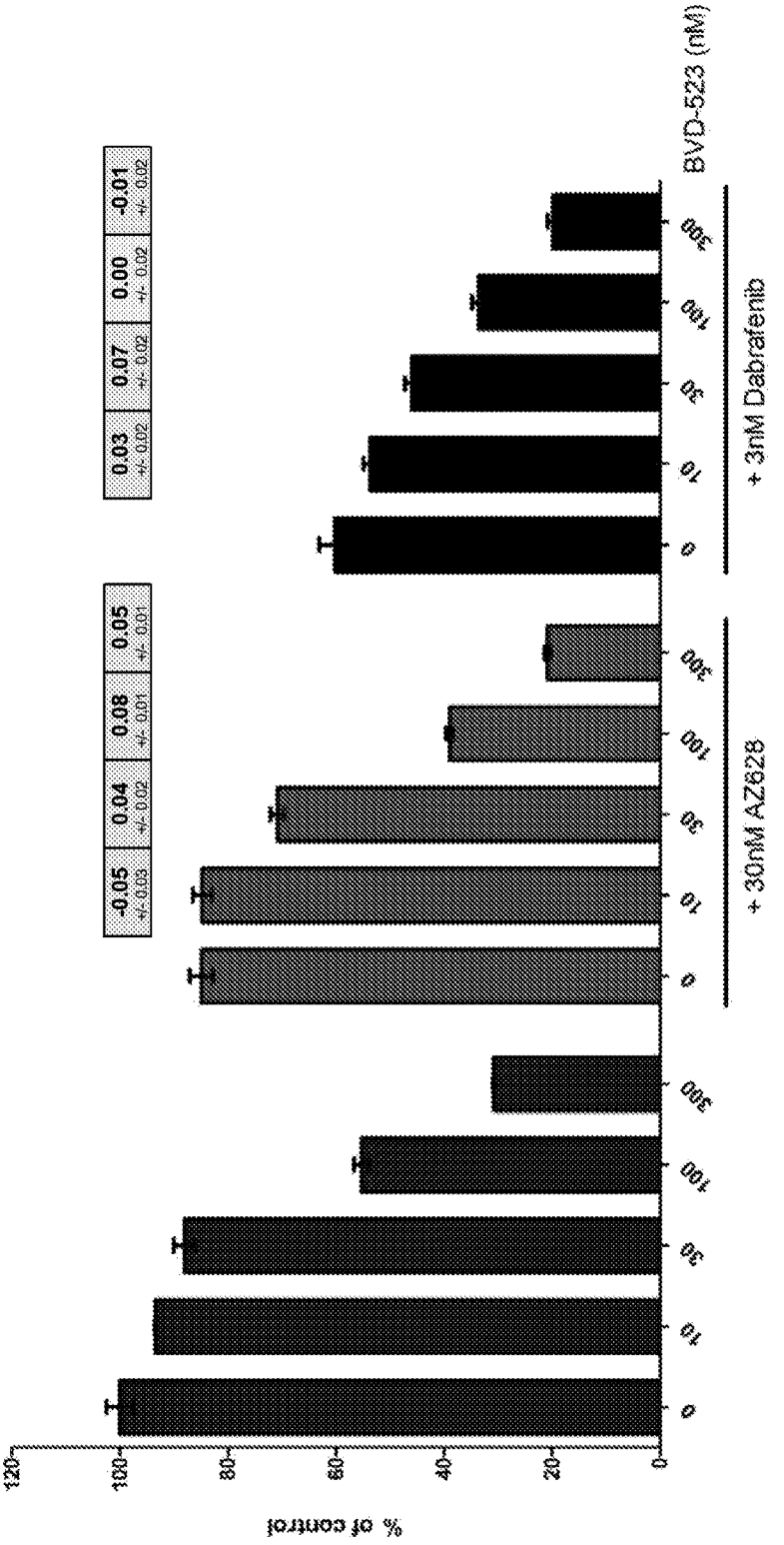

A375 - 96h Viability
-0.05 +/- 0.03
0.04 +/- 0.02
0.08 +/- 0.01
0.05 +/- 0.01
0.03 +/- 0.02
0.07 +/- 0.02
0.00 +/- 0.02
-0.01 +/- 0.02
% of control
120
100
80
60
40
20
0
0
10
30
100
300
+ 30nM AZ628
0
10
30
100
300
+ 3nM Dabrafenib
BVD-523 (nM)

FIG. 20

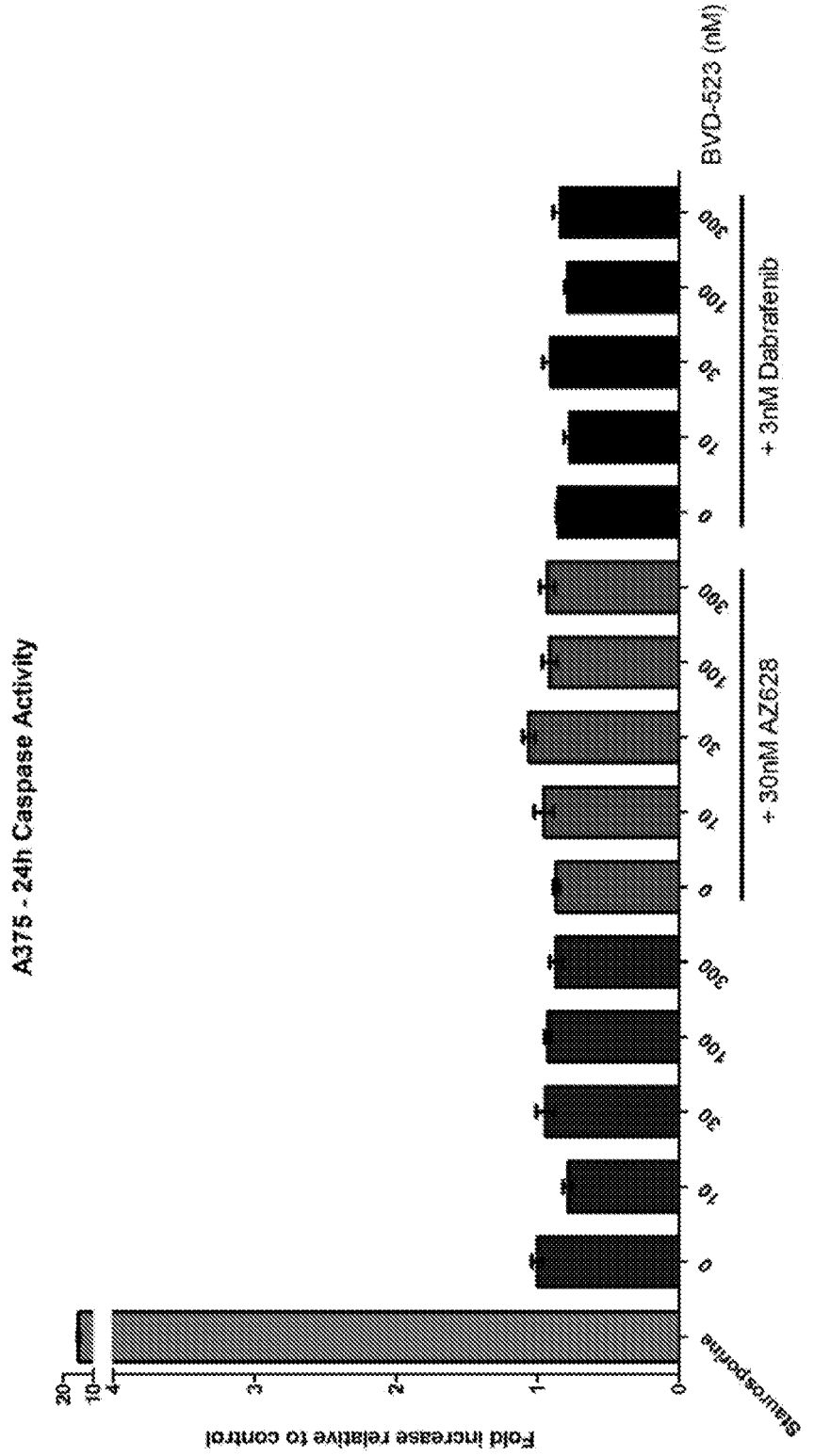

A375 - 24h Caspase Activity
Fold increase relative to control
20
10
4
3
2
1
0
Staurosporine
0
10
30
100
300
0
10
30
100
300
+ 30nM AZ628
0
10
30
100
300
+ 3nM Dabrafenib
BVD-523 (nM)

FIG. 21

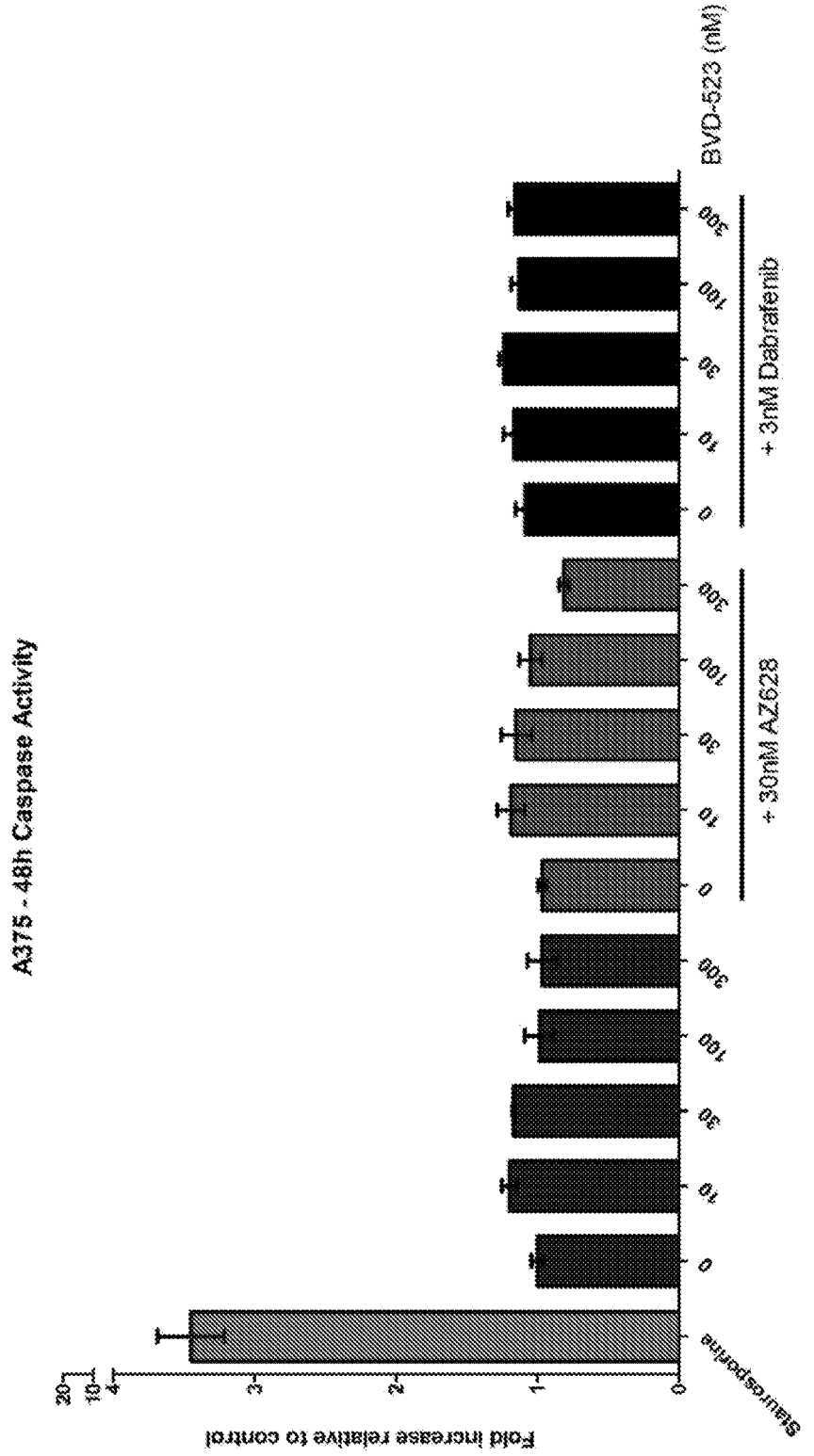

A375 - 48h Caspase Activity
Fold increase relative to control
20
10
4
3
2
1
0
Staurosporine
0
10
30
100
300
0
10
30
100
300
+ 30nM AZ628
0
10
30
100
300
+ 3nM Dabrafenib
BVD-523 (nM)

FIG. 22

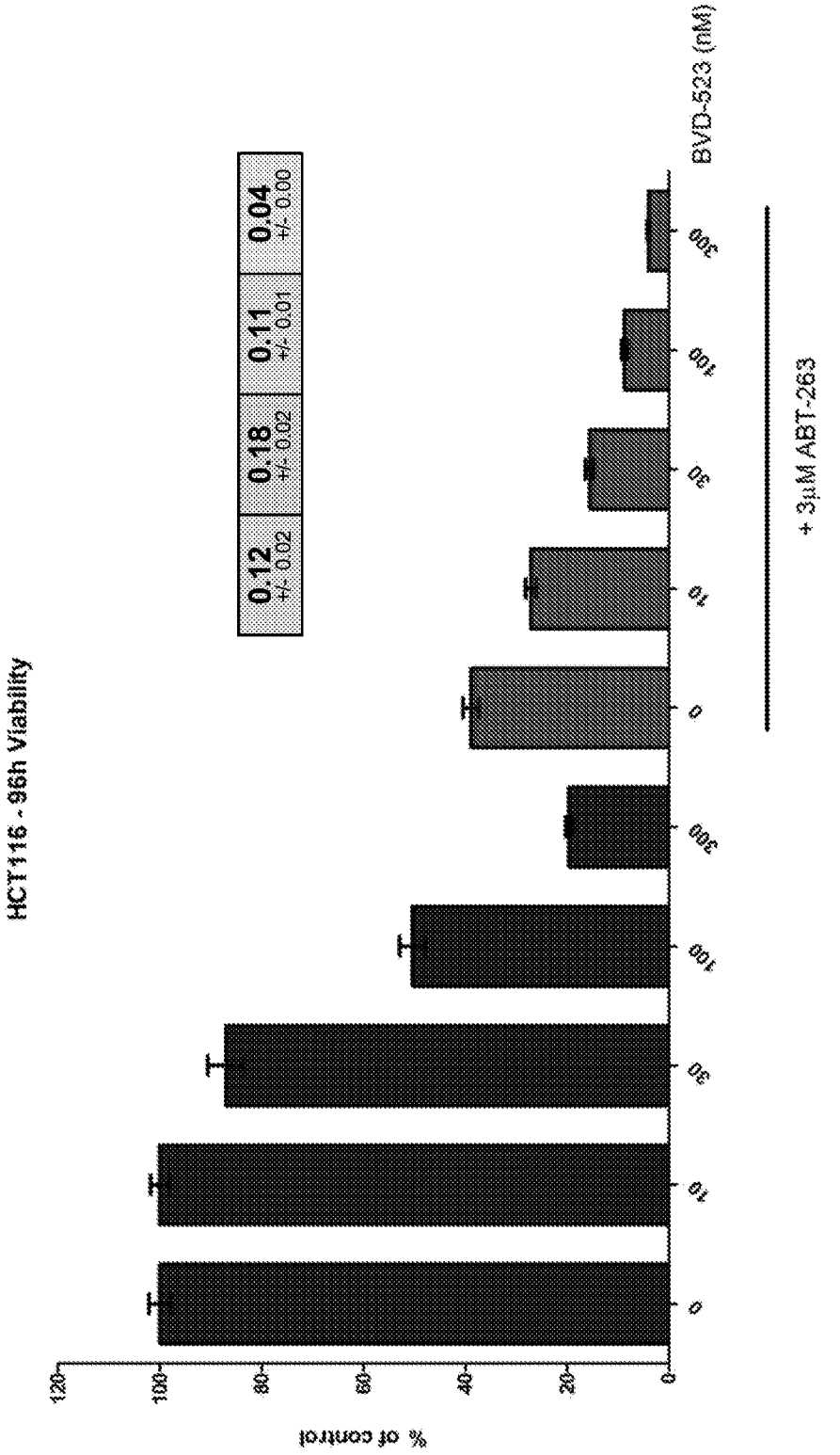

HCT116 - 96h Viability
0.12 +/- 0.02
0.18 +/- 0.02
0.11 +/- 0.01
0.04 +/- 0.00
% of control
120
100
80
60
40
20
0
0
10
30
100
300
0
10
30
100
300
BVD-523 (nM)
+ 3μM ABT-263

FIG. 23

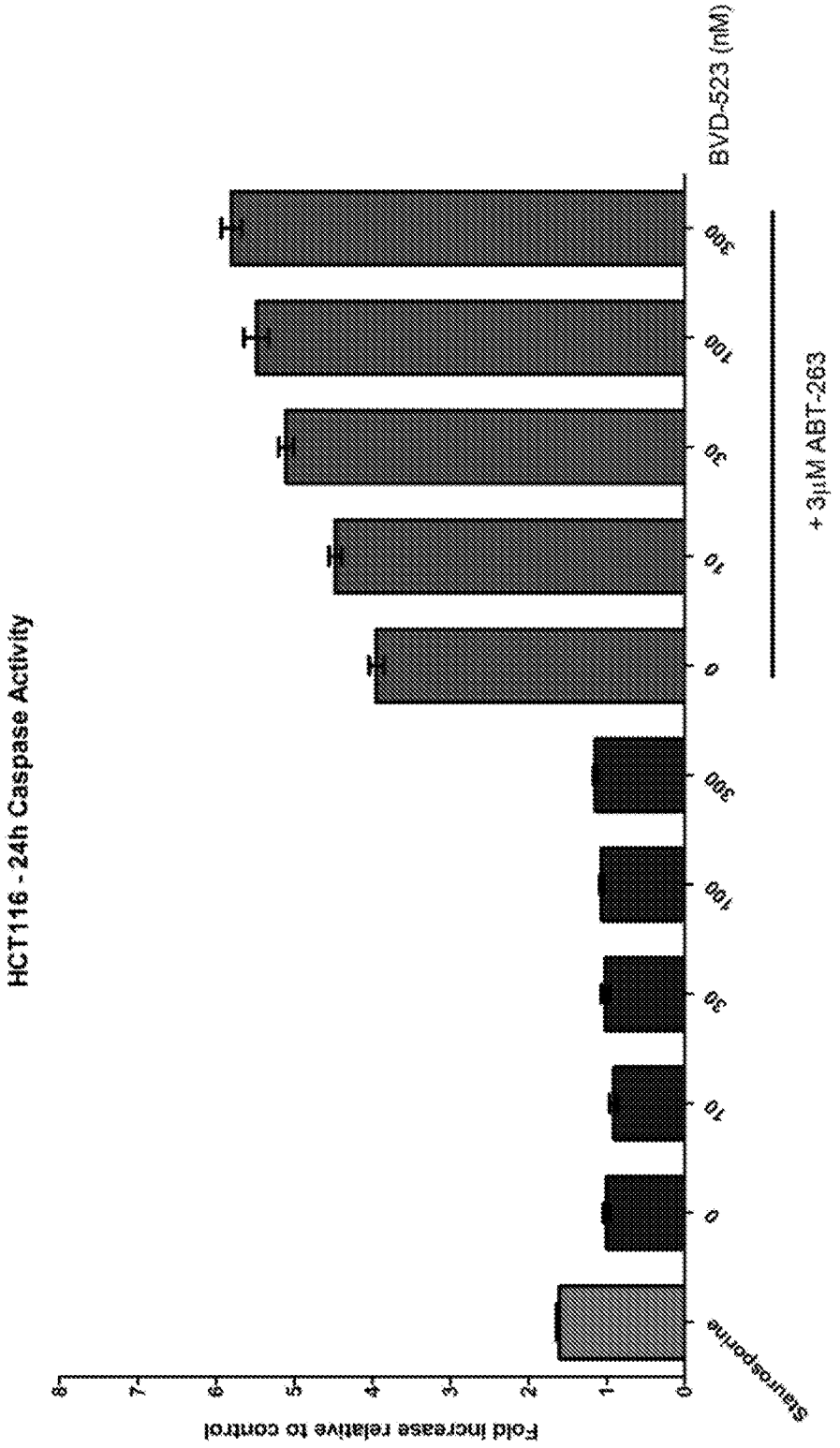

HCT116 - 24h Caspase Activity
Fold Increase relative to control
0
1
2
3
4
5
6
7
8
Staurosporine
0
10
30
100
300
0
10
30
100
300
BVD-523 (nM)
+ 3μM ABT-263

FIG. 24

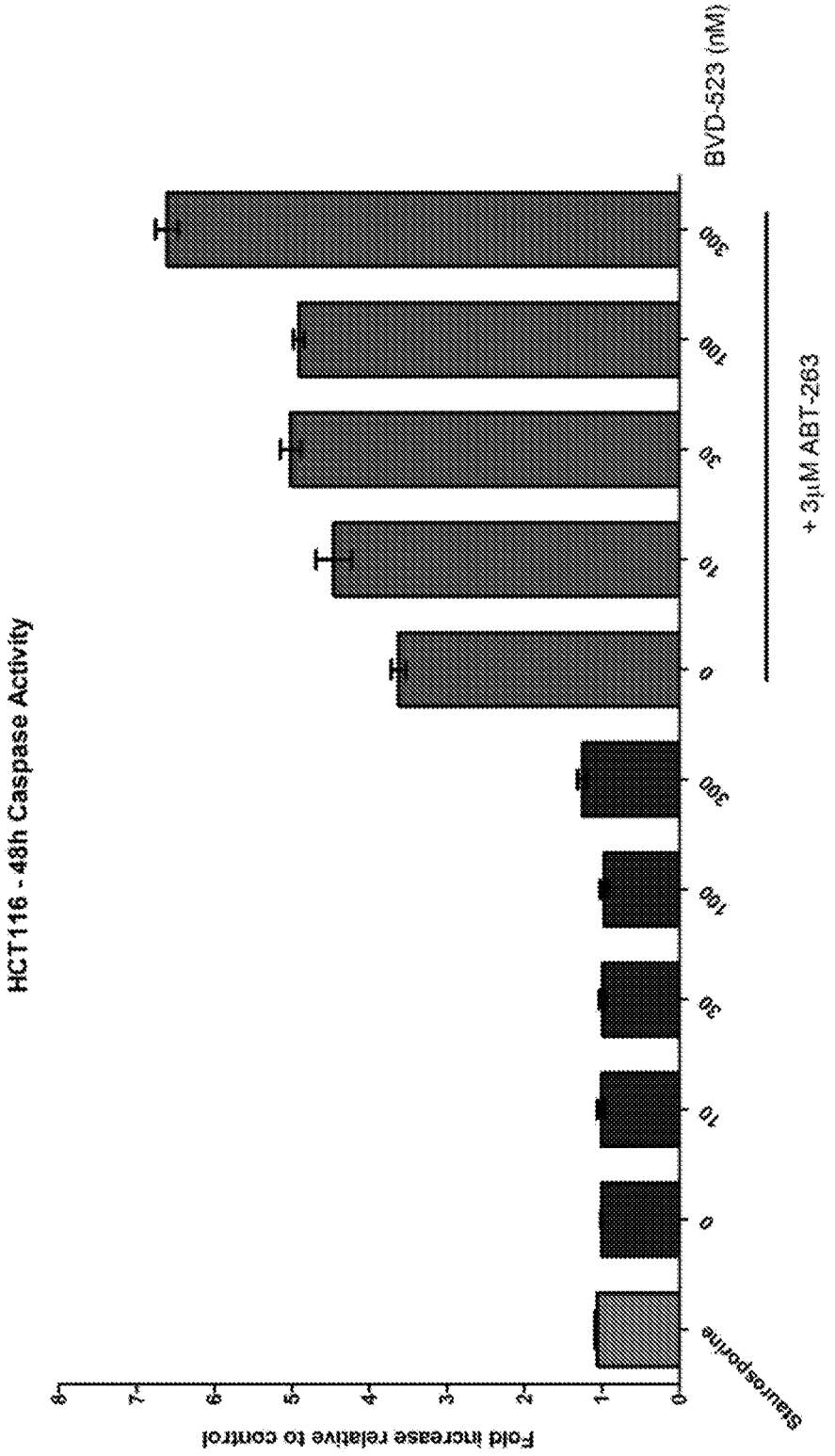

HCT116 - 48h Caspase Activity
Fold increase relative to control
0
1
2
3
4
5
6
7
8
Staurosporine
0
10
30
100
300
0
10
30
100
300
BVD-523 (nM)
+ 3μM ABT-263

FIG. 25

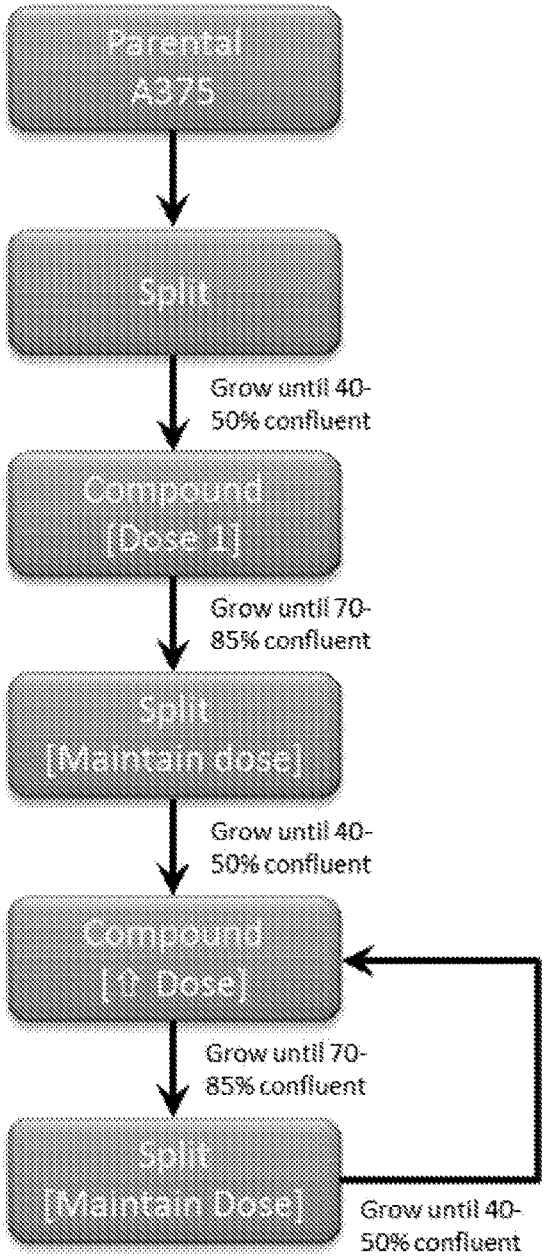

Parental
A375
Split
Grow until 40-50% confluent
Compound
[Dose 1]
Grow until 70-85% confluent
Split
[Maintain dose]
Grow until 40-50% confluent
Compound
[↑ Dose]
Grow until 70-85% confluent
Split
[Maintain Dose]
Grow until 40-50% confluent

FIG. 26

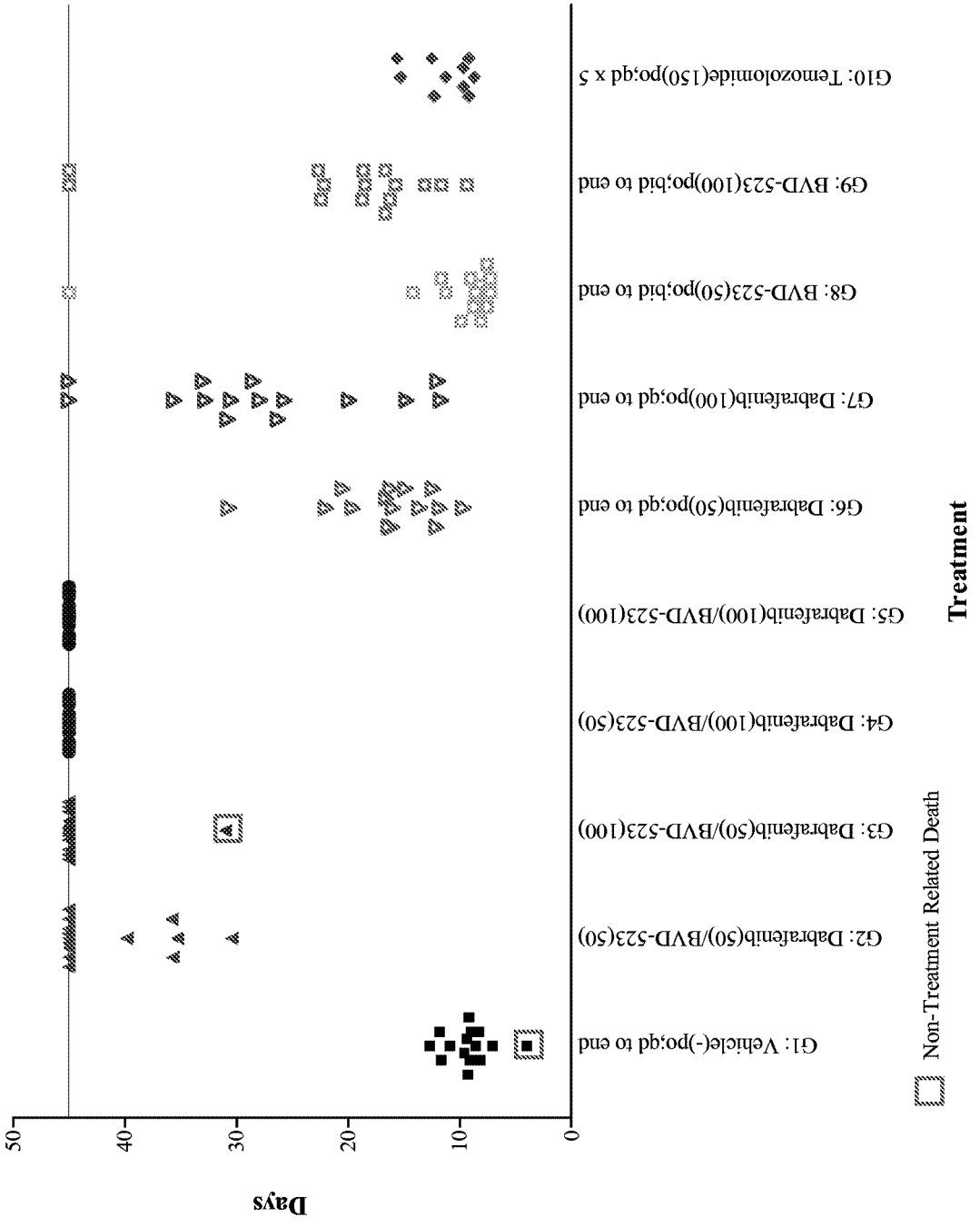

Days
0
10
20
30
40
50
G1: Vehicle(-)po;qd to end
G2: Dabrafenib(50)/BVD-523(50)
G3: Dabrafenib(50)/BVD-523(100)
G4: Dabrafenib(100)/BVD-523(50)
G5: Dabrafenib(100)/BVD-523(100)
G6: Dabrafenib(50)po;qd to end
G7: Dabrafenib(100)po;qd to end
G8: BVD-523(50)po;bid to end
G9: BVD-523(100)po;bid to end
G10: Temozolomide(150)po;qd x 5
Non-Treatment Related Death
Treatment

FIG. 27

A

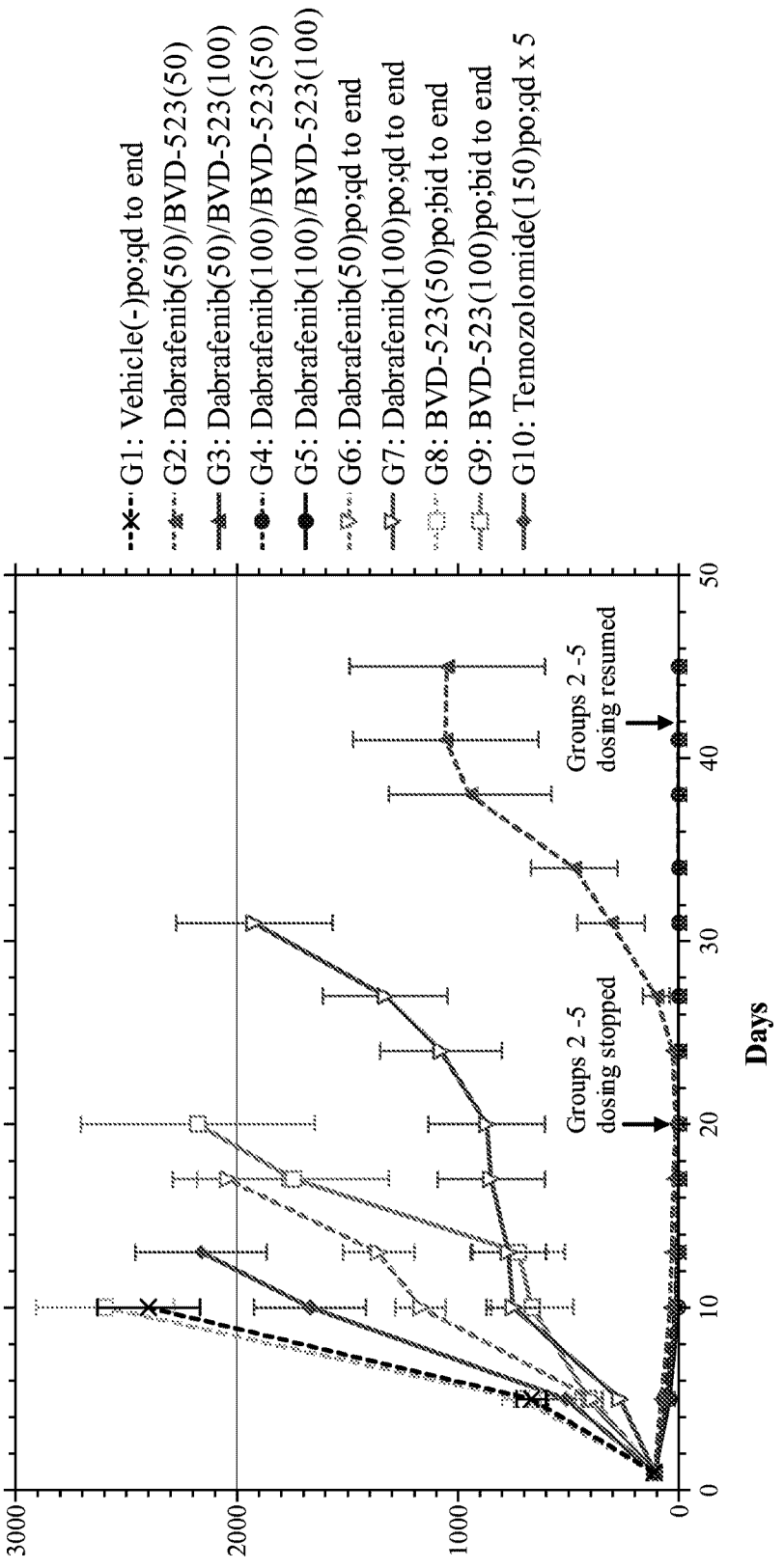

Mean Tumor Growth in the A375-e351 Study
G1: Vehicle(-)po;qd to end
G2: Dabrafenib(50)/BVD-523(50)
G3: Dabrafenib(50)/BVD-523(100)
G4: Dabrafenib(100)/BVD-523(50)
G5: Dabrafenib(100)/BVD-523(100)
G6: Dabrafenib(50)po;qd to end
G7: Dabrafenib(100)po;qd to end
G8: BVD-523(50)po;bid to end
G9: BVD-523(100)po;bid to end
G10: Temozolomide(150)po;qd x 5
Groups 2 -5 dosing stopped
Groups 2 -5 dosing resumed
Mean Tumor Volume (+/-SEM), mm 3
Days
0
1000
2000
3000
0
10
20
30
40
50

FIG. 27

B

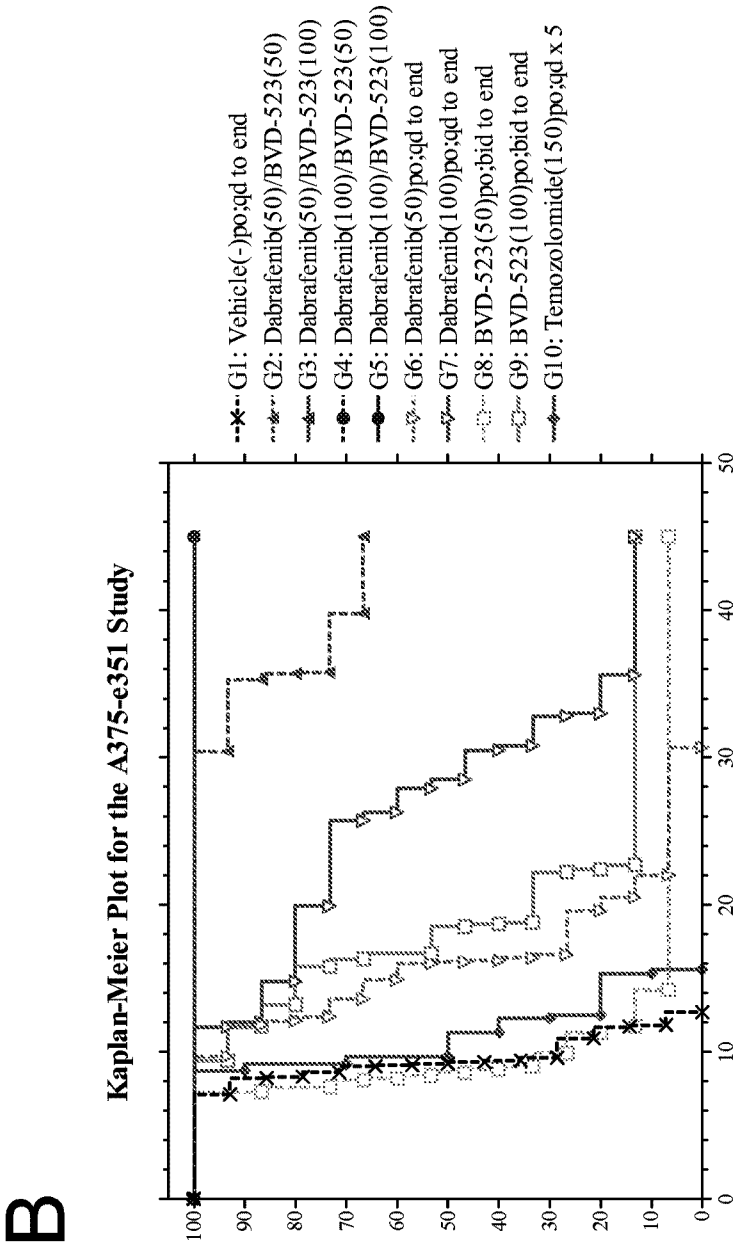

Kaplan-Meier Plot for the A375-e351 Study
G1: Vehicle(-)po;qd to end
G2: Dabrafenib(50)/BVD-523(50)
G3: Dabrafenib(50)/BVD-523(100)
G4: Dabrafenib(100)/BVD-523(50)
G5: Dabrafenib(100)/BVD-523(100)
G6: Dabrafenib(50)po;qd to end
G7: Dabrafenib(100)po;qd to end
G8: BVD-523(50)po;bid to end
G9: BVD-523(100)po;bid to end
G10: Temozolomide(150)po;qd x 5
100
90
80
70
60
50
40
30
20
10
0
0
10
20
30
40
50

FIG. 28

A

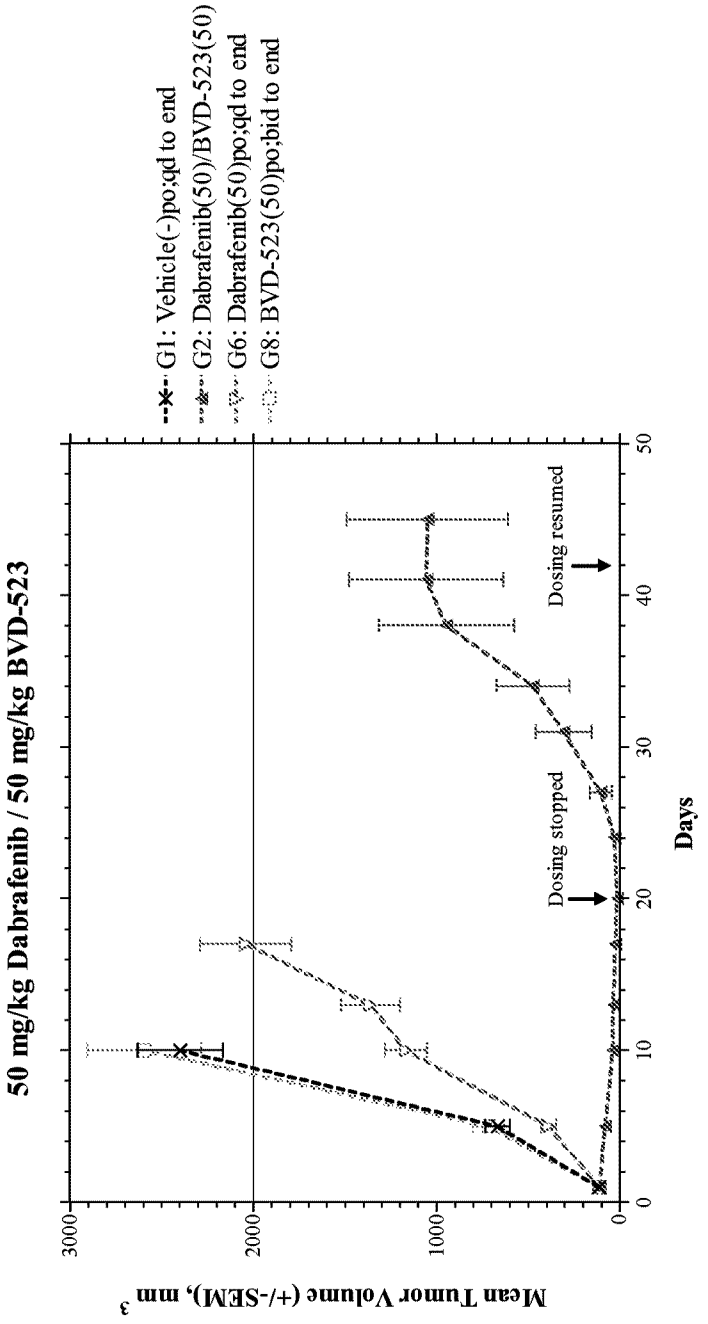

50 mg/kg Dabrafenib / 50 mg/kg BVD-523
G1: Vehicle(-)po;qd to end
G2: Dabrafenib(50)/BVD-523(50)
G6: Dabrafenib(50)po;qd to end
G8: BVD-523(50)po;bid to end
Dosing stopped
Dosing resumed
Mean Tumor Volume (+/-SEM), mm 3
Days
0
1000
2000
3000
0
10
20
30
40
50

FIG. 28 Con't

B

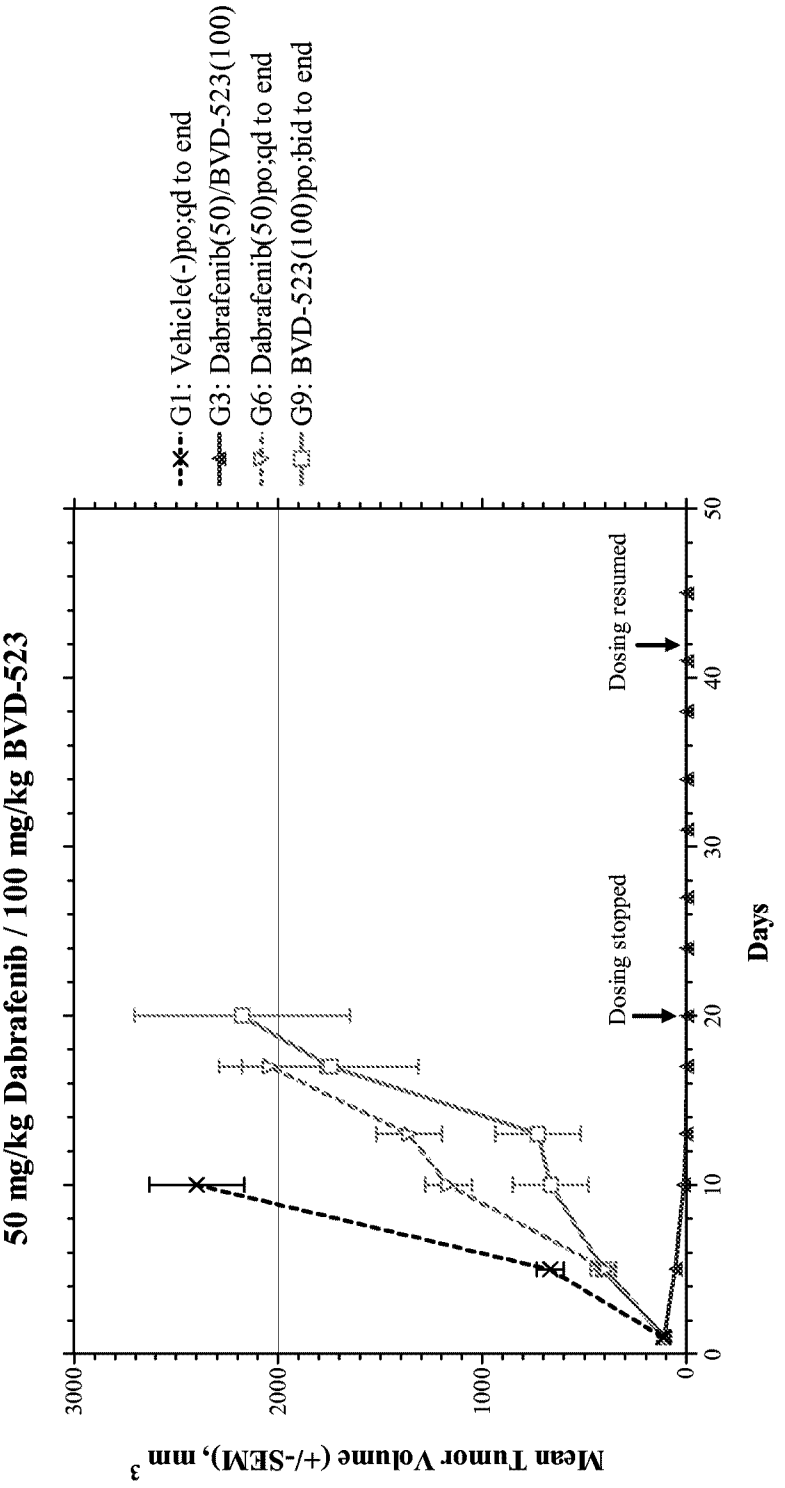

50 mg/kg Dabrafenib / 100 mg/kg BVD-523
G1: Vehicle(-)po;qd to end
G3: Dabrafenib(50)/BVD-523(100)
G6: Dabrafenib(50)po;qd to end
G9: BVD-523(100)po;bid to end
Dosing stopped
Dosing resumed
Mean Tumor Volume (+/-SEM), mm 3
Days
0
1000
2000
3000
0
10
20
30
40
50

FIG. 28 Con't

C

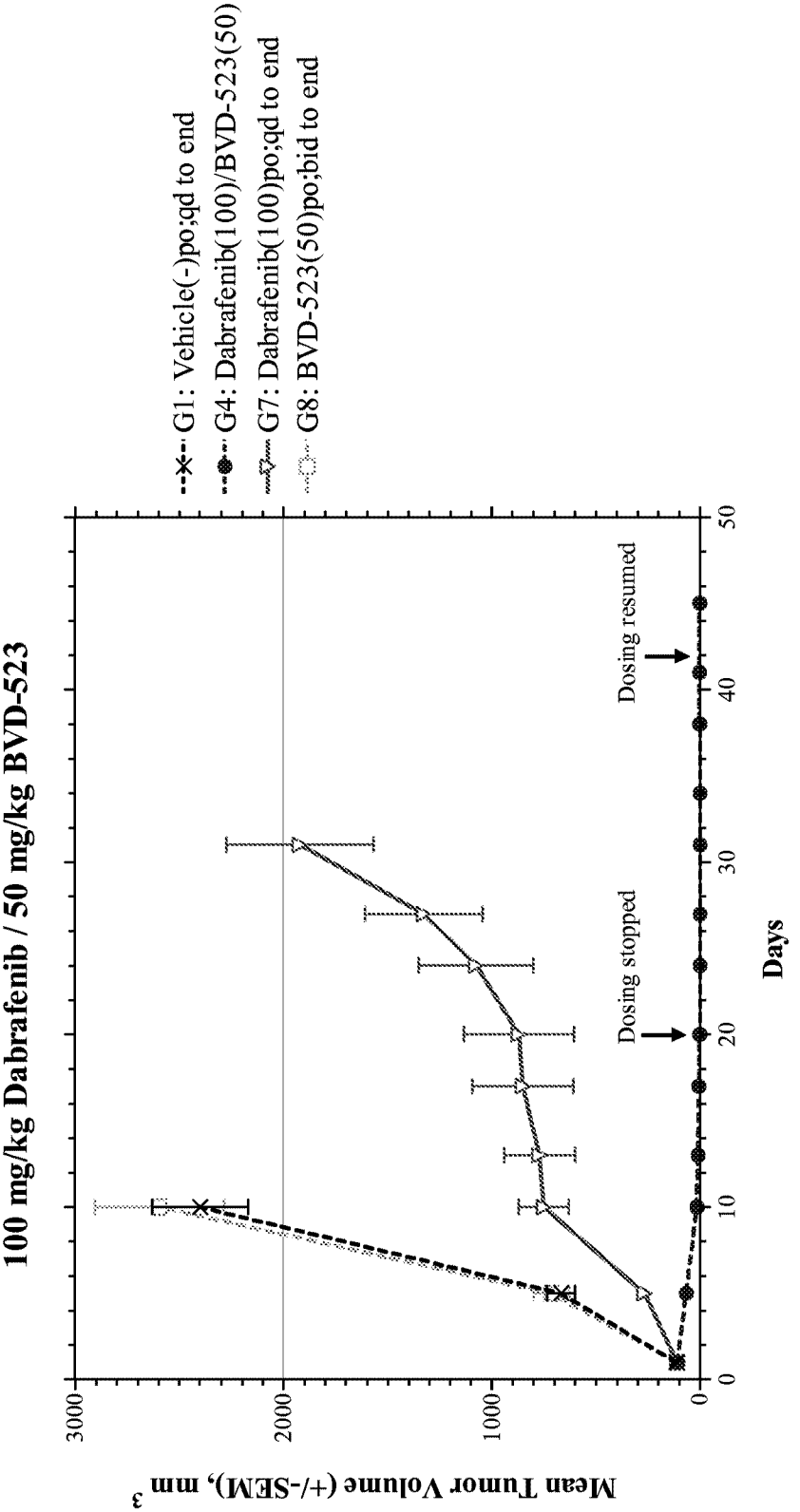

100 mg/kg Dabrafenib / 50 mg/kg BVD-523
G1: Vehicle(-)po;qd to end
G4: Dabrafenib(100)/BVD-523(50)
G7: Dabrafenib(100)po;qd to end
G8: BVD-523(50)po;bid to end
Dosing stopped
Dosing resumed
Mean Tumor Volume (+/-SEM), mm 3
Days
0
1000
2000
3000
0
10
20
30
40
50

FIG. 28 Con't

D

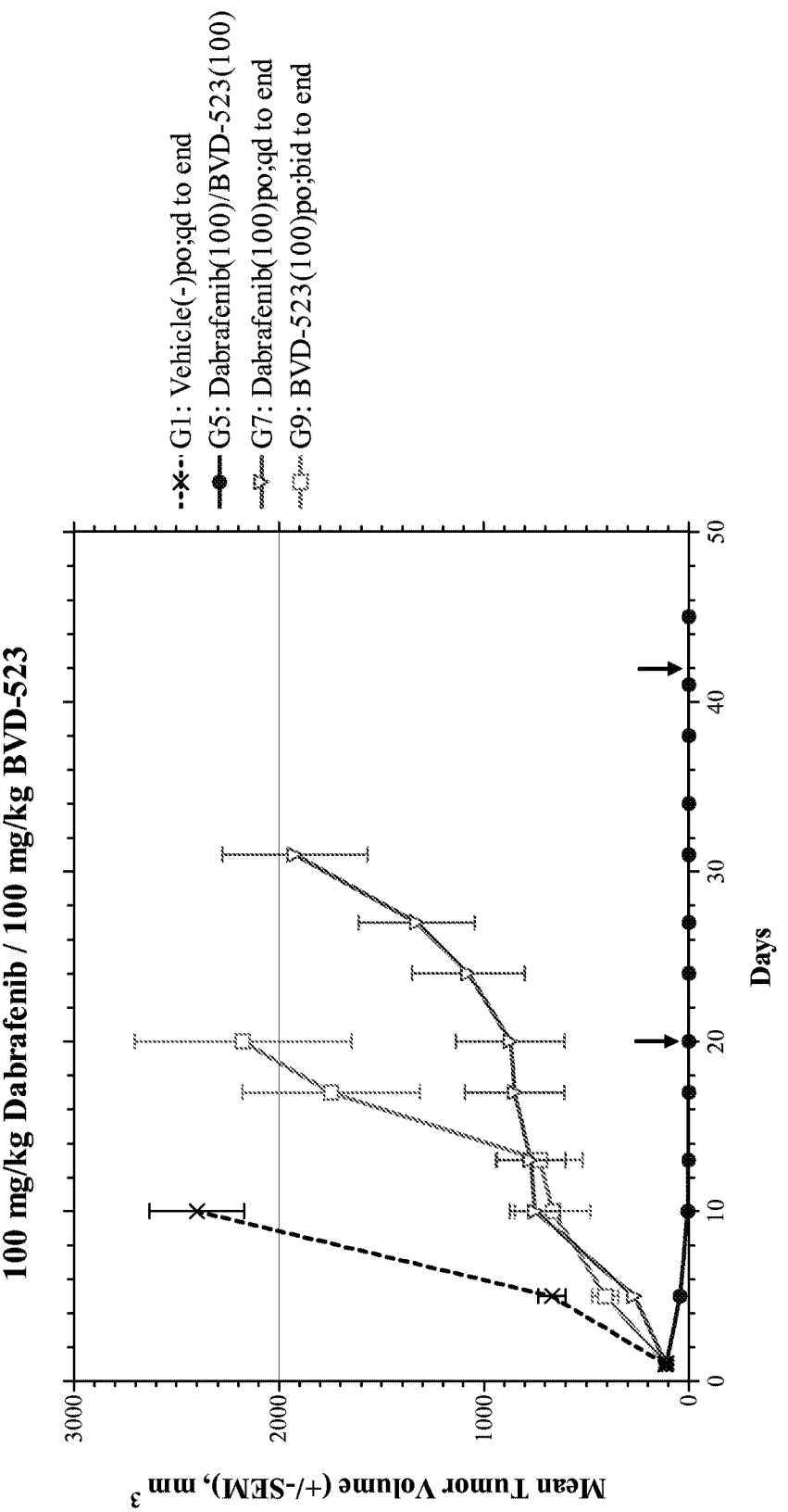

100 mg/kg Dabrafenib / 100 mg/kg BVD-523
G1: Vehicle(-)po;qd to end
G5: Dabrafenib(100)/BVD-523(100)
G7: Dabrafenib(100)po;qd to end
G9: BVD-523(100)po;bid to end
Mean Tumor Volume (+/-SEM), mm 3
Days
0
1000
2000
3000
0
10
20
30
40
50

FIG. 29

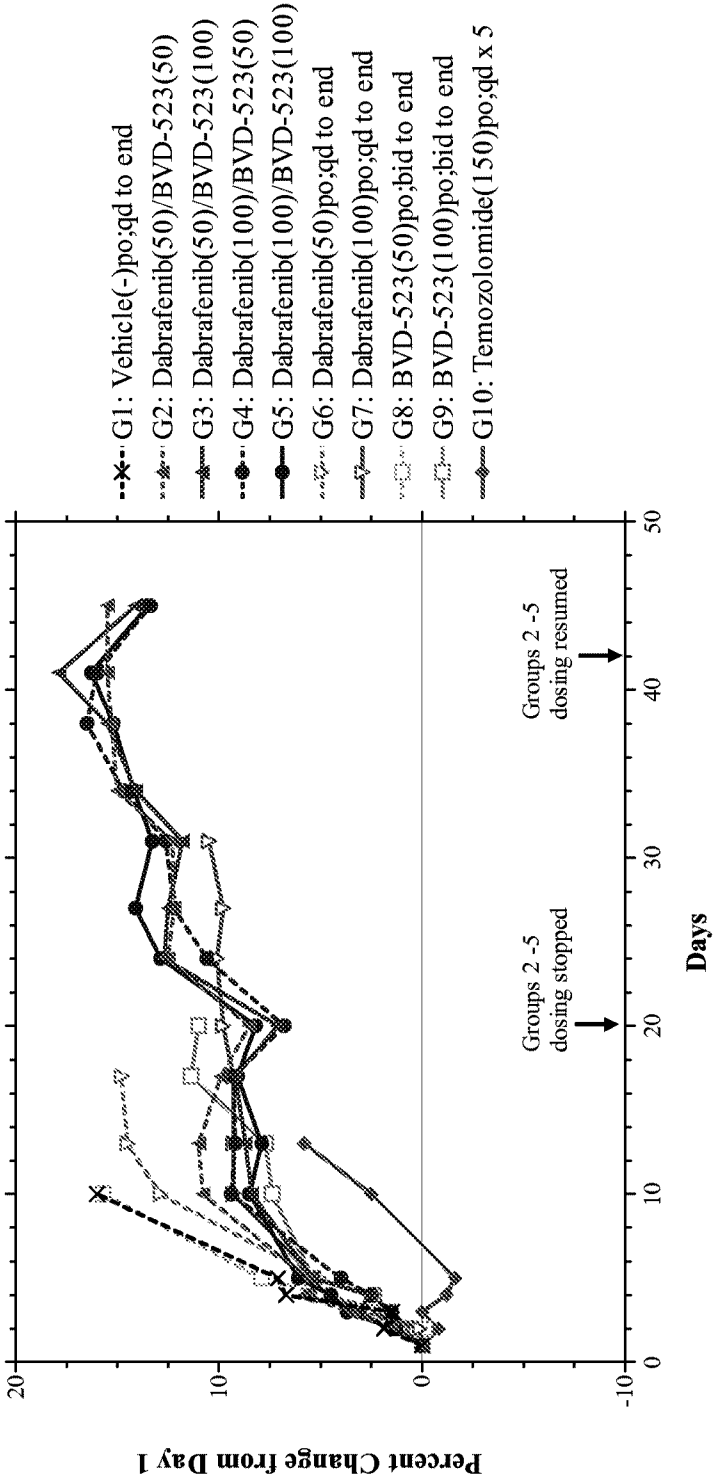

G1: Vehicle(-)po;qd to end
G2: Dabrafenib(50)/BVD-523(50)
G3: Dabrafenib(50)/BVD-523(100)
G4: Dabrafenib(100)/BVD-523(50)
G5: Dabrafenib(100)/BVD-523(100)
G6: Dabrafenib(50)po;qd to end
G7: Dabrafenib(100)po;qd to end
G8: BVD-523(50)po;bid to end
G9: BVD-523(100)po;bid to end
G10: Temozolomide(150)po;qd x 5
Groups 2 -5 dosing stopped
Groups 2 -5 dosing resumed
Percent Change from Day 1
Days
20
10
0
-10
0
10
20
30
40
50

FIG. 30

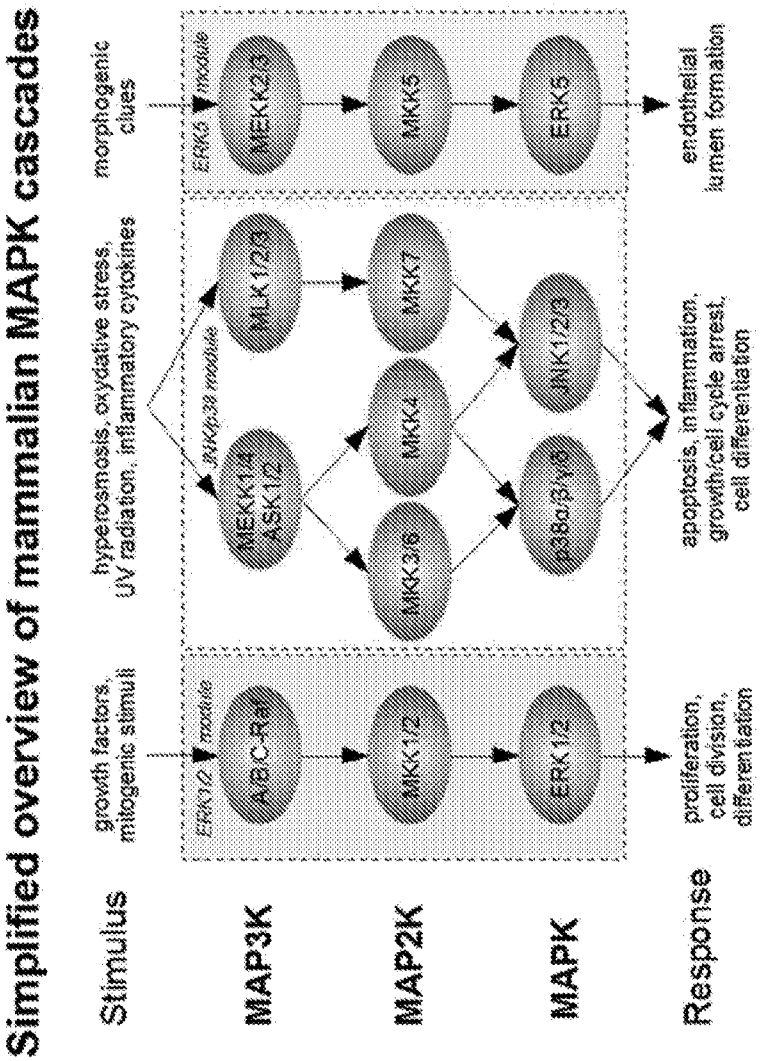

Simplified overview of mammalian MAPK cascades
Stimulus
MAP3K
MAP2K
MAPK
Response
growth factors, mitogenic stimuli
hyperosmosis, oxydative stress, UV radiation, inflammatory cytokines
morphogenic clues
ERK1/2 module
JNK/p38 module
ERK5 module
A/B/C-Raf
MEKK1/4 ASK1/2
MLK1/2/3
MEKK2/3
MKK1/2
MKK3/6
MKK4
MKK7
MKK5
ERK1/2
p38α/β1/β
JNK1/2/3
ERK5
proliferation, cell division, differentiation
apoptosis, inflammation, growth/cell cycle arrest, cell differentiation
endothelial lumen formation

FIG. 31

HCT116: AZ628/Trametinib Combination Assay – Alamar Blue

A

% Inhibition:

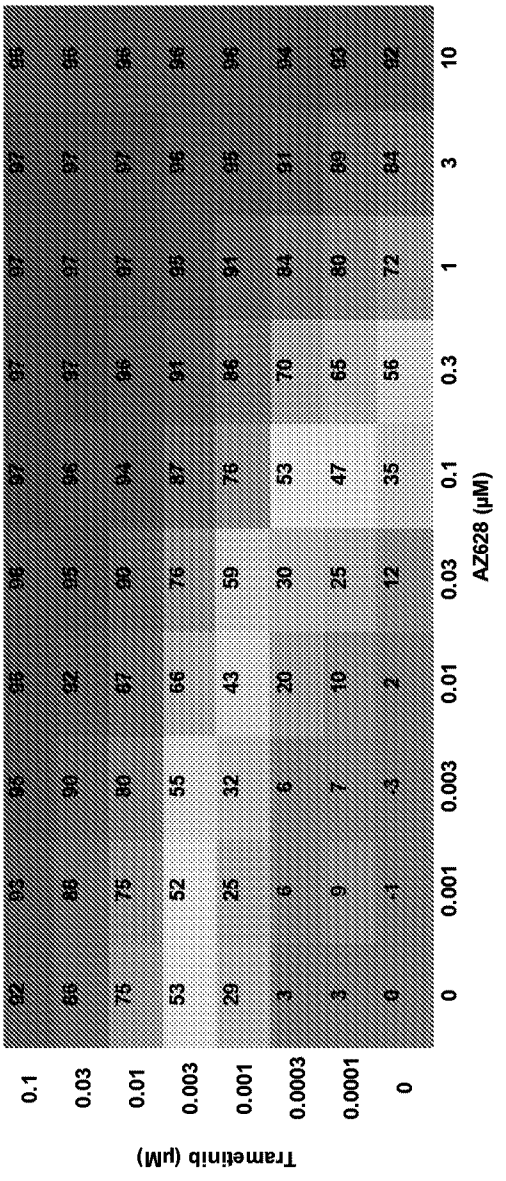
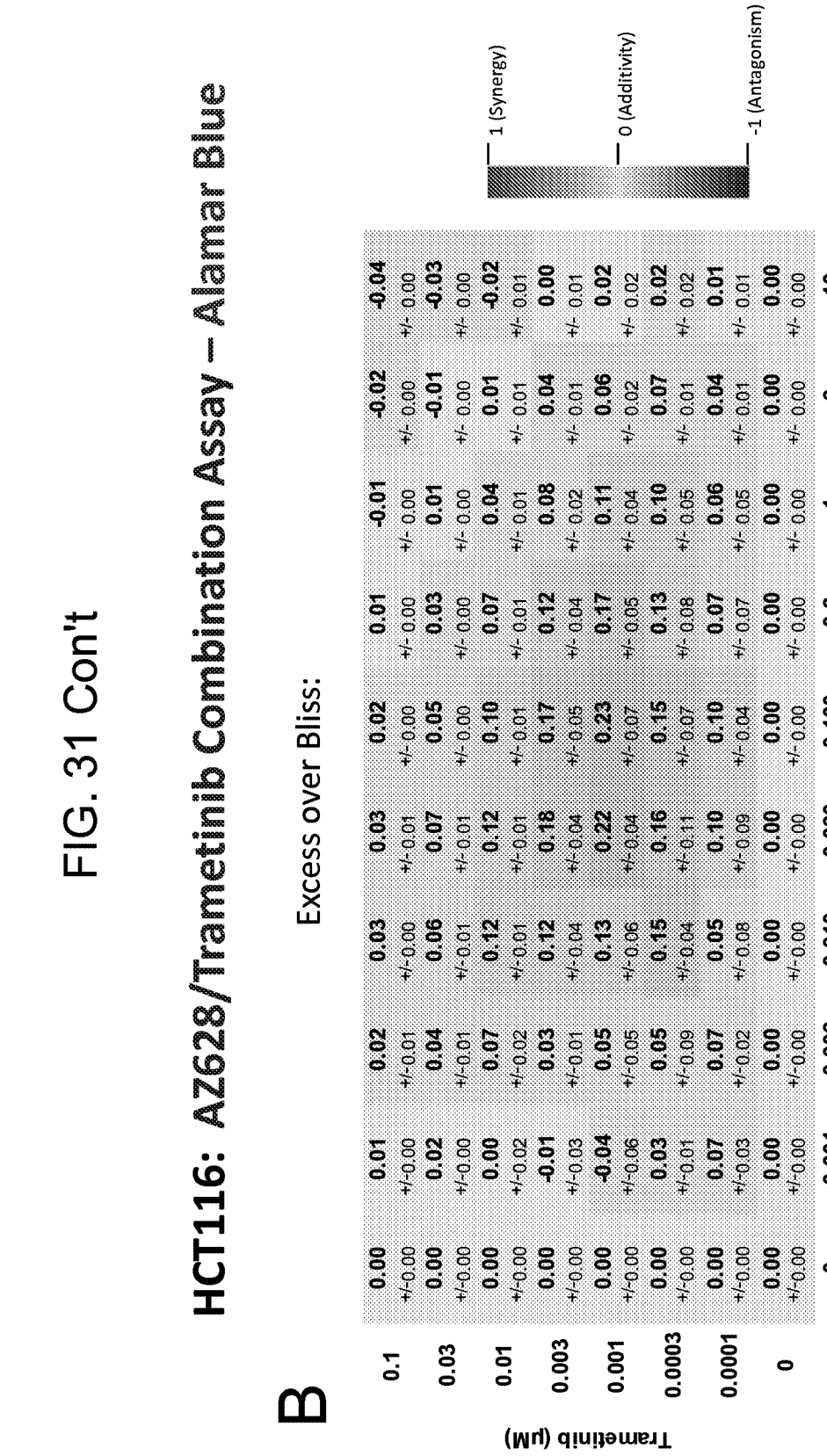


FIG. 31 Con't



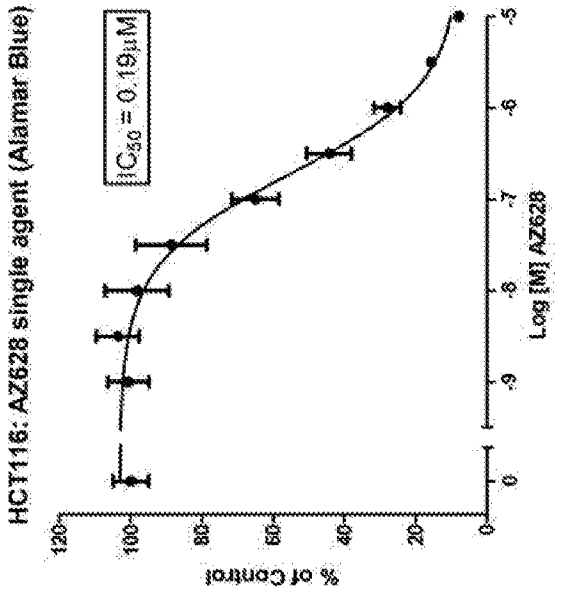
Trametinib (μM) \ AZ628 (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
0.1	0.00 +/-0.00	0.01 +/-0.00	0.02 +/-0.01	0.03 +/-0.00	0.03 +/-0.01	0.02 +/-0.00	0.01 +/- 0.00	-0.01 +/- 0.00	-0.02 +/- 0.00	-0.04 +/- 0.00
0.03	0.00 +/-0.00	0.02 +/-0.00	0.04 +/-0.01	0.06 +/-0.01	0.07 +/- 0.01	0.05 +/- 0.00	0.03 +/- 0.00	0.01 +/- 0.00	-0.01 +/- 0.00	-0.03 +/- 0.00
0.01	0.00 +/-0.00	0.00 +/-0.02	0.07 +/-0.02	0.12 +/-0.01	0.12 +/- 0.01	0.10 +/- 0.01	0.07 +/- 0.01	0.04 +/- 0.01	0.01 +/- 0.01	-0.02 +/- 0.01
0.003	0.00 +/-0.00	-0.01 +/-0.03	0.03 +/-0.01	0.12 +/-0.04	0.18 +/- 0.04	0.17 +/- 0.05	0.12 +/- 0.04	0.08 +/- 0.02	0.04 +/- 0.01	0.00 +/- 0.01
0.001	0.00 +/-0.00	-0.04 +/-0.06	0.05 +/-0.05	0.13 +/-0.06	0.22 +/- 0.04	0.23 +/- 0.07	0.17 +/- 0.05	0.11 +/- 0.04	0.06 +/- 0.02	0.02 +/- 0.02
0.0003	0.00 +/-0.00	0.03 +/-0.01	0.05 +/-0.09	0.15 +/-0.04	0.16 +/- 0.11	0.15 +/- 0.07	0.13 +/- 0.08	0.10 +/- 0.05	0.07 +/- 0.01	0.02 +/- 0.02
0.0001	0.00 +/-0.00	0.07 +/-0.03	0.07 +/-0.02	0.05 +/-0.08	0.10 +/- 0.09	0.10 +/- 0.04	0.07 +/- 0.07	0.06 +/- 0.05	0.04 +/- 0.01	0.01 +/- 0.01
0	0.00 +/-0.00	0.00 +/-0.00	0.00 +/-0.00	0.00 +/-0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

FIG. 31 Con't

HCT116: AZ628/Trametinib Combination Assay – Alamar Blue

Single agent and Potentiation plots:

C



D

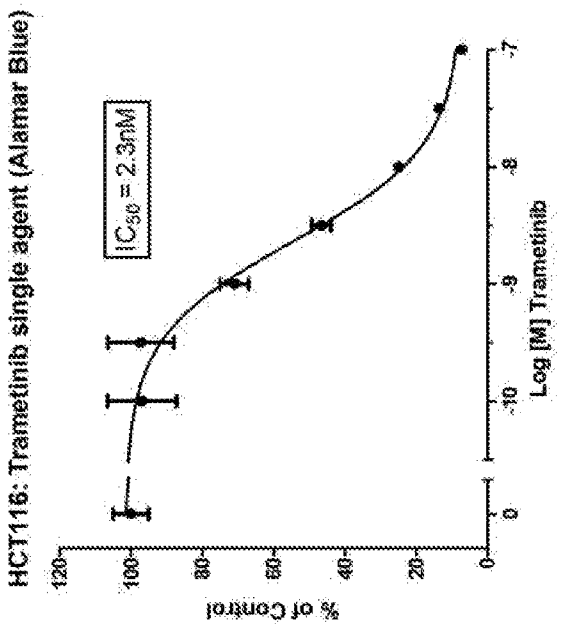


FIG. 31 Con't

HCT116: AZ628/Trametinib Combination Assay – Alamar Blue

E

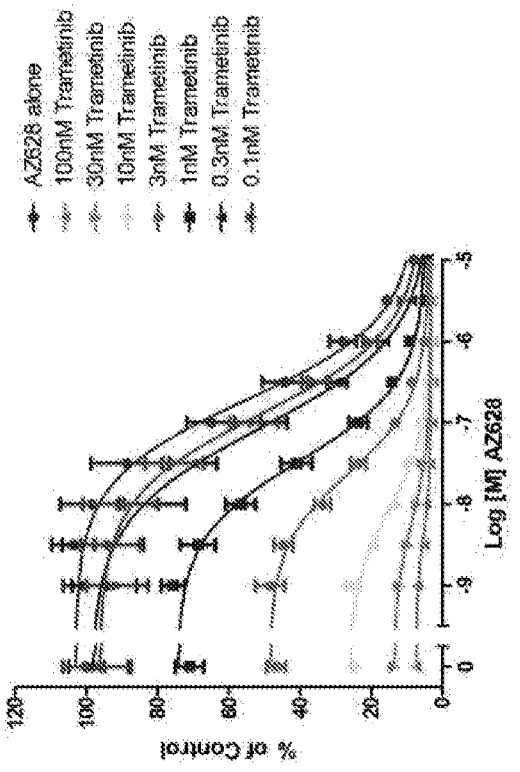


FIG. 32

HCT116: AZ628/BVD-523 Combination Assay – Alamar Blue

A

% Inhibition:

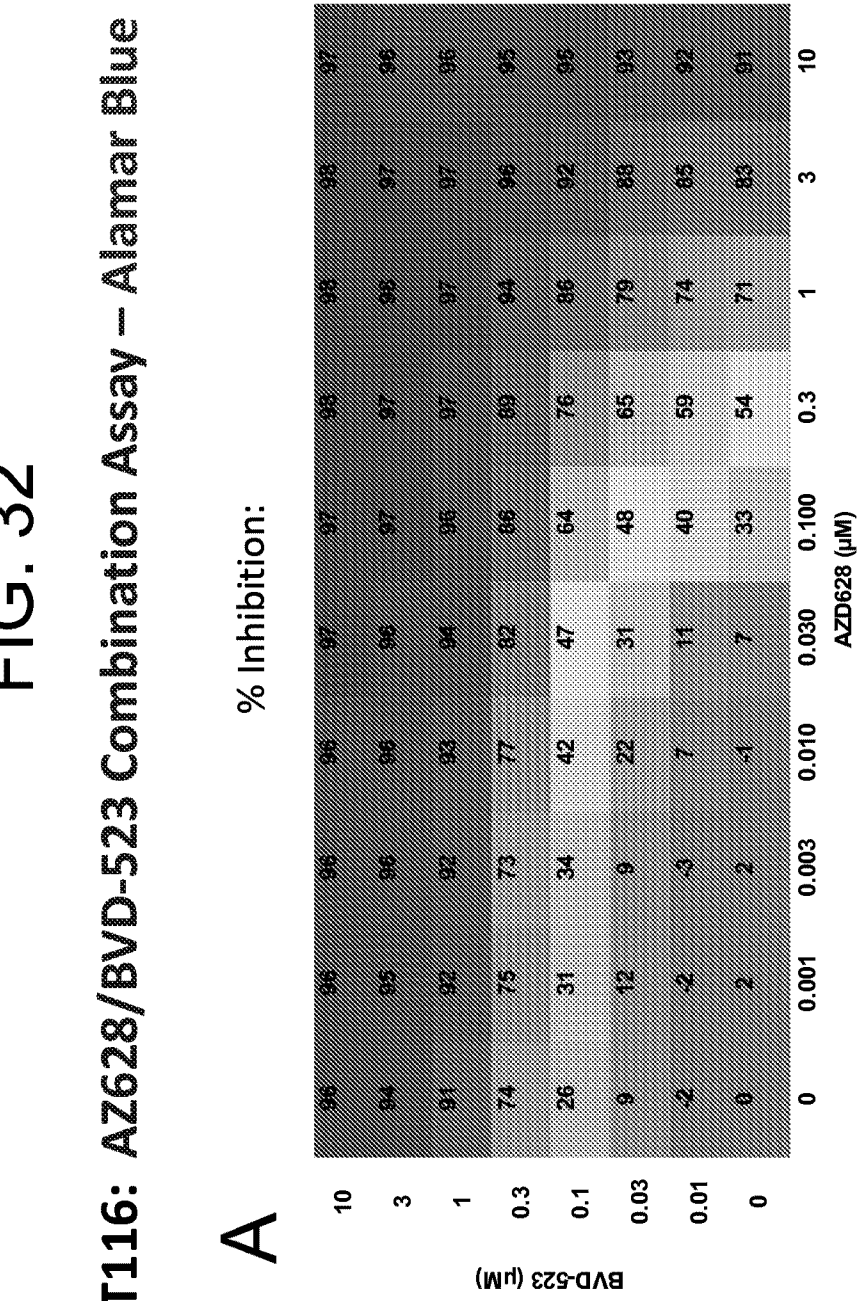


FIG. 32 Con't

HCT116: AZ628/BVD-523 Combination Assay – Alamar Blue

B

Excess over Bliss:

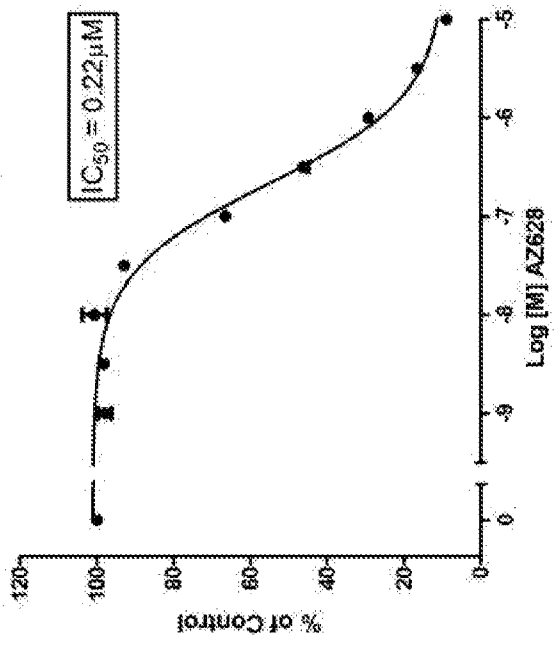
BVD-523 (μM) \ AZD628 (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
10	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.01 +/- 0.00	0.01 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	-0.01 +/- 0.00	-0.02 +/- 0.00	-0.03 +/- 0.00
3	0.00 +/- 0.00	0.01 +/- 0.00	0.01 +/- 0.00	0.02 +/- 0.01	0.02 +/- 0.00	0.01 +/- 0.00	0.00 +/- 0.00	-0.01 +/- 0.00	-0.02 +/- 0.00	-0.03 +/- 0.00
1	0.00 +/- 0.00	0.01 +/- 0.01	0.01 +/- 0.00	0.03 +/- 0.01	0.03 +/- 0.00	0.02 +/- 0.00	0.01 +/- 0.00	0.00 +/- 0.00	-0.01 +/- 0.00	-0.03 +/- 0.00
0.3	0.00 +/- 0.00	0.00 +/- 0.03	-0.02 +/- 0.04	0.03 +/- 0.03	0.06 +/- 0.02	0.03 +/- 0.01	0.01 +/- 0.01	0.01 +/- 0.01	0.00 +/- 0.01	-0.02 +/- 0.00
0.1	0.00 +/- 0.00	0.03 +/- 0.06	0.06 +/- 0.07	0.16 +/- 0.08	0.15 +/- 0.06	0.14 +/- 0.04	0.11 +/- 0.03	0.08 +/- 0.02	0.05 +/- 0.01	0.01 +/- 0.01
0.03	0.00 +/- 0.00	0.01 +/- 0.04	-0.02 +/- 0.07	0.13 +/- 0.07	0.16 +/- 0.06	0.09 +/- 0.04	0.07 +/- 0.04	0.06 +/- 0.03	0.03 +/- 0.01	0.01 +/- 0.01
0.01	0.00 +/- 0.00	-0.02 +/- 0.06	-0.02 +/- 0.03	0.10 +/- 0.02	0.06 +/- 0.06	0.08 +/- 0.05	0.06 +/- 0.06	0.04 +/- 0.01	0.02 +/- 0.02	0.01 +/- 0.01
0	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

FIG. 32 Con't

HCT116: AZ628/BVD-523 Combination Assay – Alamar Blue

Single agent and Potentiation plots:

C



D

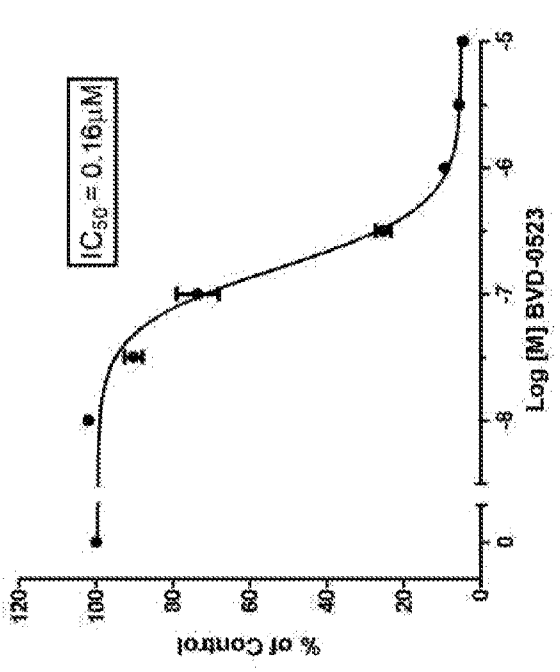


FIG. 32 Con't

HCT116: AZ628/BVD-523 Combination Assay – Alamar Blue

E

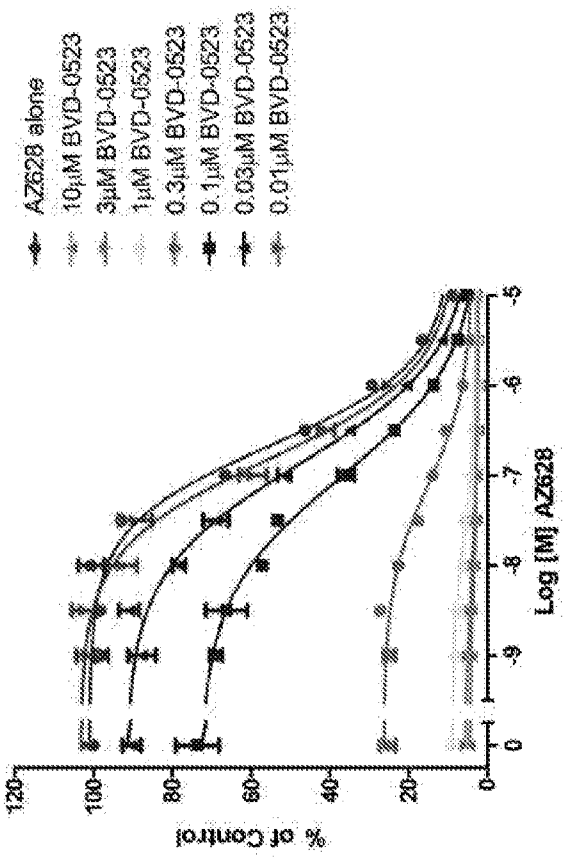


FIG. 33

HCT116: Sorafenib/Trametinib Combination Assay – Alamar Blue

A

% Inhibition:

Trametinib (μM) \ Sorafenib (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
0.1	93	93	93	93	96	97	98	97	100	
0.03	87	86	86	86	91	94	96	96	99	
0.01	74	76	74	70	78	87	92	84	98	
0.003	49	53	44	44	47	64	82	89	98	
0.001	24	28	29	27	27	39	65	82	98	
0.0003	2	8	8	6	6	14	39	70	98	
0.0001	2	1	1	6	7	11	30	61	98	
0	0	1	0	-2	0	3	18	54	98	

FIG. 33 Con't

HCT116: Sorafenib/Trametinib Combination Assay – Alamar Blue

B

Excess over Bliss:

Trametinib (μM) \ Sorafenib (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
0.1	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.01 +/- 0.00	0.03 +/- 0.00	0.04 +/- 0.00	0.04 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00
0.03	0.00 +/- 0.00	0.00 +/- 0.01	-0.01 +/- 0.01	-0.01 +/- 0.01	-0.01 +/- 0.02	0.04 +/- 0.01	0.07 +/- 0.01	0.07 +/- 0.01	0.02 +/- 0.00	0.00 +/- 0.00
0.01	0.00 +/- 0.00	0.01 +/- 0.02	0.00 +/- 0.02	-0.03 +/- 0.03	-0.05 +/- 0.01	0.03 +/- 0.03	0.12 +/- 0.00	0.14 +/- 0.01	0.06 +/- 0.01	0.00 +/- 0.00
0.003	0.00 +/- 0.00	0.04 +/- 0.08	-0.04 +/- 0.09	-0.04 +/- 0.05	-0.08 +/- 0.03	-0.03 +/- 0.02	0.14 +/- 0.03	0.25 +/- 0.04	0.12 +/- 0.02	0.00 +/- 0.00
0.001	0.00 +/- 0.00	0.04 +/- 0.07	0.05 +/- 0.09	0.05 +/- 0.01	0.01 +/- 0.06	0.02 +/- 0.05	0.13 +/- 0.01	0.28 +/- 0.05	0.17 +/- 0.03	0.00 +/- 0.00
0.0003	0.00 +/- 0.00	0.05 +/- 0.06	0.05 +/- 0.09	0.05 +/- 0.09	0.04 +/- 0.10	0.01 +/- 0.09	0.09 +/- 0.05	0.19 +/- 0.09	0.15 +/- 0.04	0.00 +/- 0.00
0.0001	0.00 +/- 0.00	-0.01 +/- 0.01	0.00 +/- 0.11	0.06 +/- 0.04	0.05 +/- 0.06	0.02 +/- 0.05	0.06 +/- 0.02	0.10 +/- 0.04	0.06 +/- 0.01	0.00 +/- 0.00
0	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

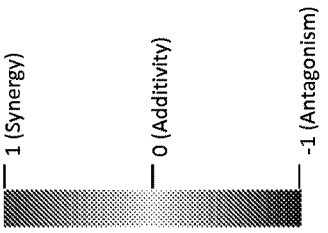


FIG. 33 Con't

HCT116: Sorafenib/Trametinib Combination Assay – Alamar Blue

Single agent and Potentiation plots:

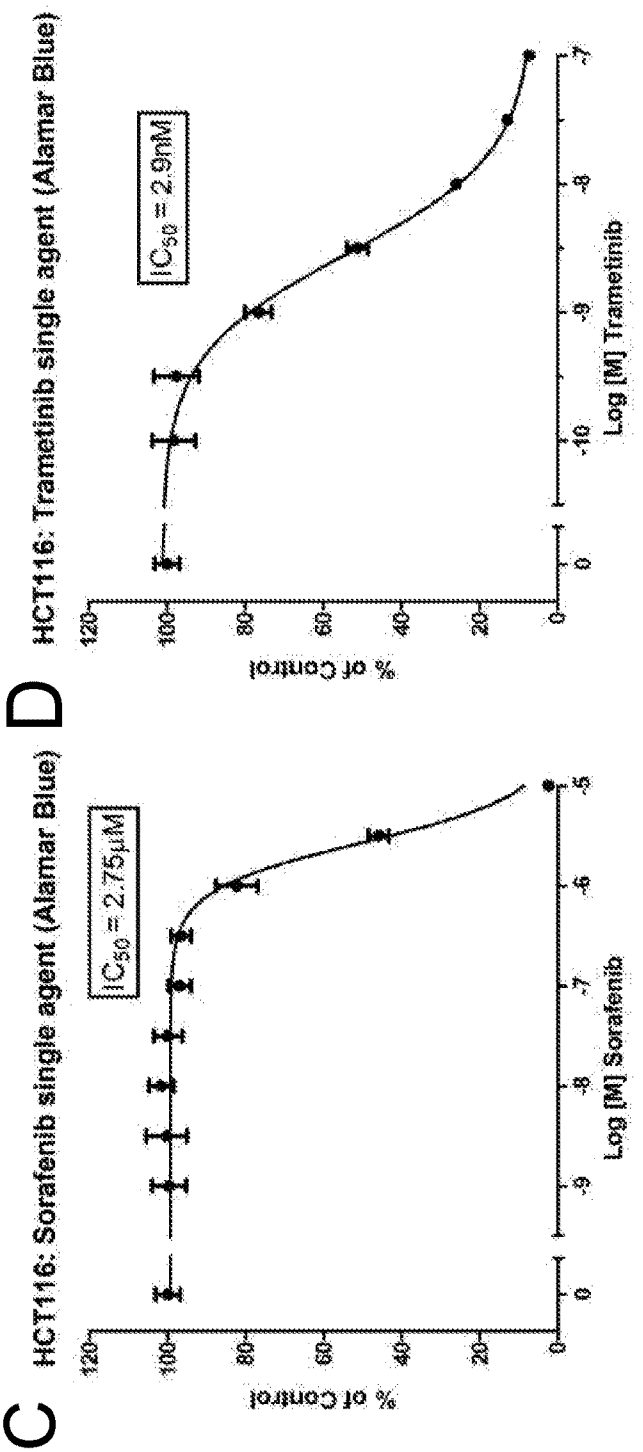


FIG. 33 Con't

HCT116: Sorafenib/Trametinib Combination Assay – Alamar Blue

E

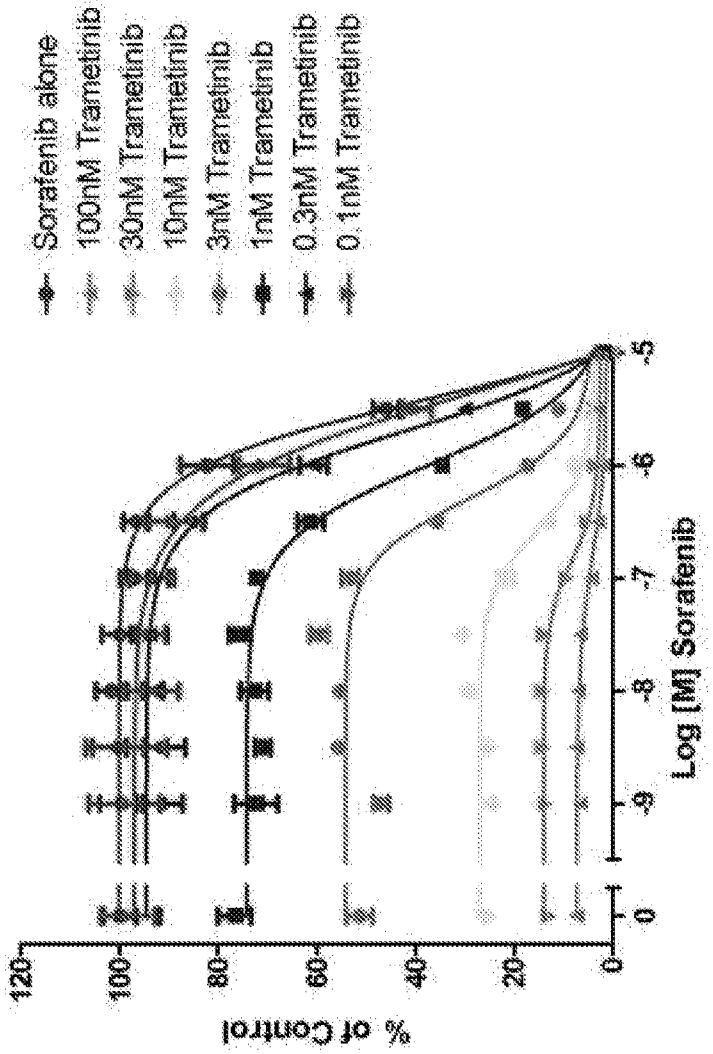


FIG. 34

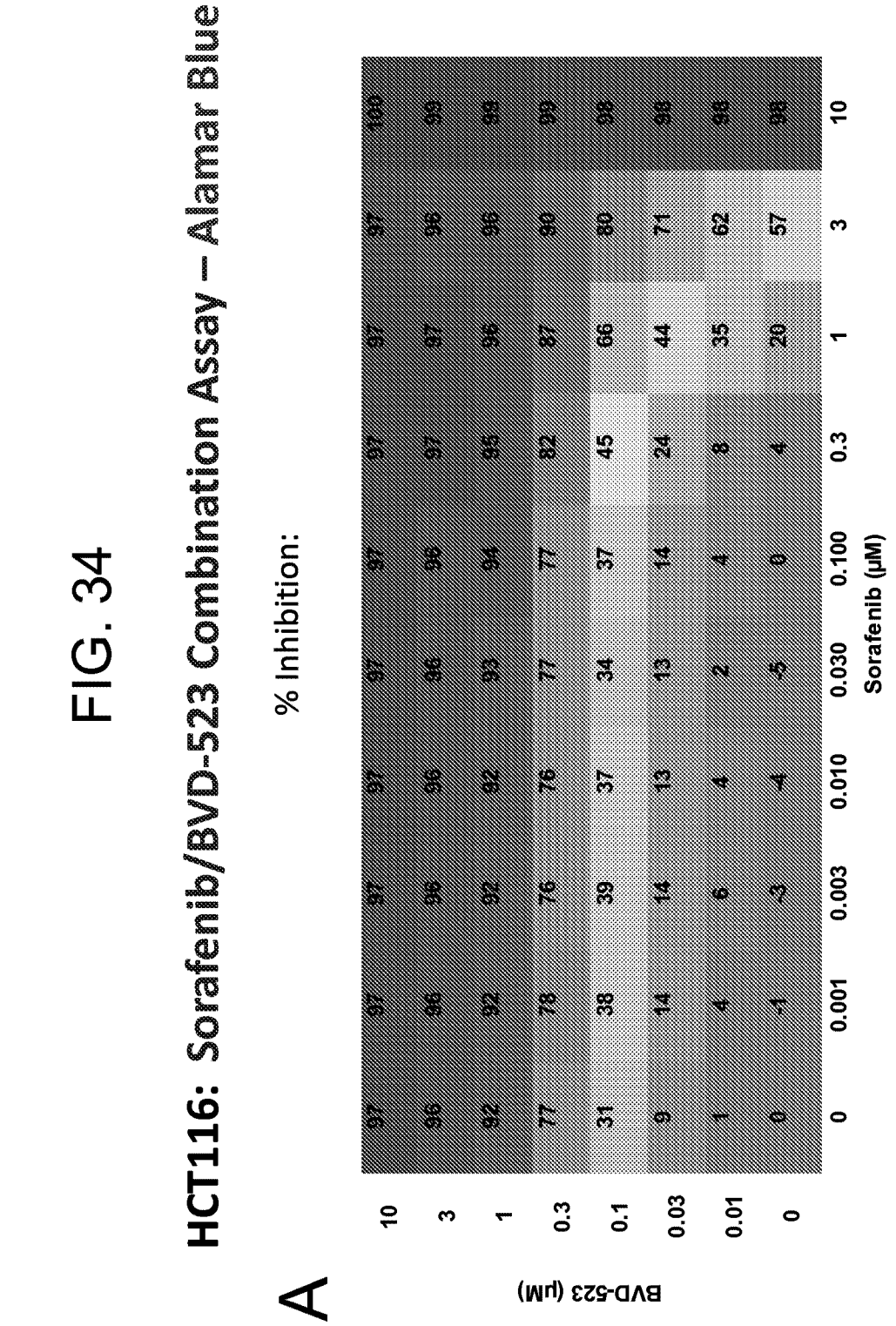

HCT116: Sorafenib/BVD-523 Combination Assay – Alamar Blue
A
% Inhibition:
BVD-523 (μM)
10 97 97 97 97 97 97 97 97 97 97 100
3 96 96 96 96 96 96 97 97 96 96 99
1 92 92 92 92 93 94 95 96 96 96 98
0.3 77 78 76 76 77 77 82 87 90 90 98
0.1 31 38 39 37 34 37 45 66 80 80 98
0.03 9 14 14 13 13 14 24 44 71 71 98
0.01 1 4 6 4 2 4 8 35 62 62 98
0 0 -1 -3 -4 -5 0 4 20 57 57 98
0 0.001 0.003 0.010 0.030 0.100 0.3 1 3 10
Sorafenib (μM)

FIG. 34 Con't

HCT116: Sorafenib/BVD-523 Combination Assay – Alamar Blue

B

Excess over Bliss:

BVD-523 (μM) \ Sorafenib (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
10	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.01 +/- 0.00	0.00 +/- 0.00	-0.02 +/- 0.00	0.00 +/- 0.00	
3	0.00 +/- 0.00	0.00 +/- 0.01	0.00 +/- 0.00	0.00 +/- 0.01	0.01 +/- 0.00	0.01 +/- 0.00	0.00 +/- 0.00	-0.02 +/- 0.00	-0.01 +/- 0.00	
1	0.00 +/- 0.00	0.00 +/- 0.00	0.01 +/- 0.00	0.00 +/- 0.00	0.02 +/- 0.01	0.03 +/- 0.01	0.02 +/- 0.00	-0.01 +/- 0.00	-0.01 +/- 0.00	
0.3	0.00 +/- 0.00	0.02 +/- 0.04	0.00 +/- 0.02	0.00 +/- 0.03	0.02 +/- 0.03	0.00 +/- 0.02	0.04 +/- 0.01	0.05 +/- 0.01	0.00 +/- 0.00	-0.01 +/- 0.00
0.1	0.00 +/- 0.00	0.07 +/- 0.07	0.10 +/- 0.03	0.08 +/- 0.07	0.06 +/- 0.10	0.05 +/- 0.08	0.11 +/- 0.06	0.21 +/- 0.07	0.10 +/- 0.03	0.00 +/- 0.00
0.03	0.00 +/- 0.00	0.05 +/- 0.08	0.08 +/- 0.06	0.07 +/- 0.03	0.08 +/- 0.04	0.05 +/- 0.06	0.11 +/- 0.06	0.17 +/- 0.05	0.10 +/- 0.06	0.00 +/- 0.00
0.01	0.00 +/- 0.00	0.03 +/- 0.03	0.08 +/- 0.04	0.07 +/- 0.01	0.05 +/- 0.02	0.02 +/- 0.01	0.03 +/- 0.02	0.14 +/- 0.01	0.05 +/- 0.02	0.00 +/- 0.00
0	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

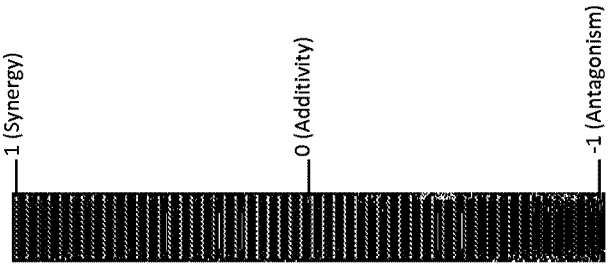


FIG. 34 Con't

HCT116: Sorafenib/BVD-523 Combination Assay – Alamar Blue

Single agent and Potentiation plots:

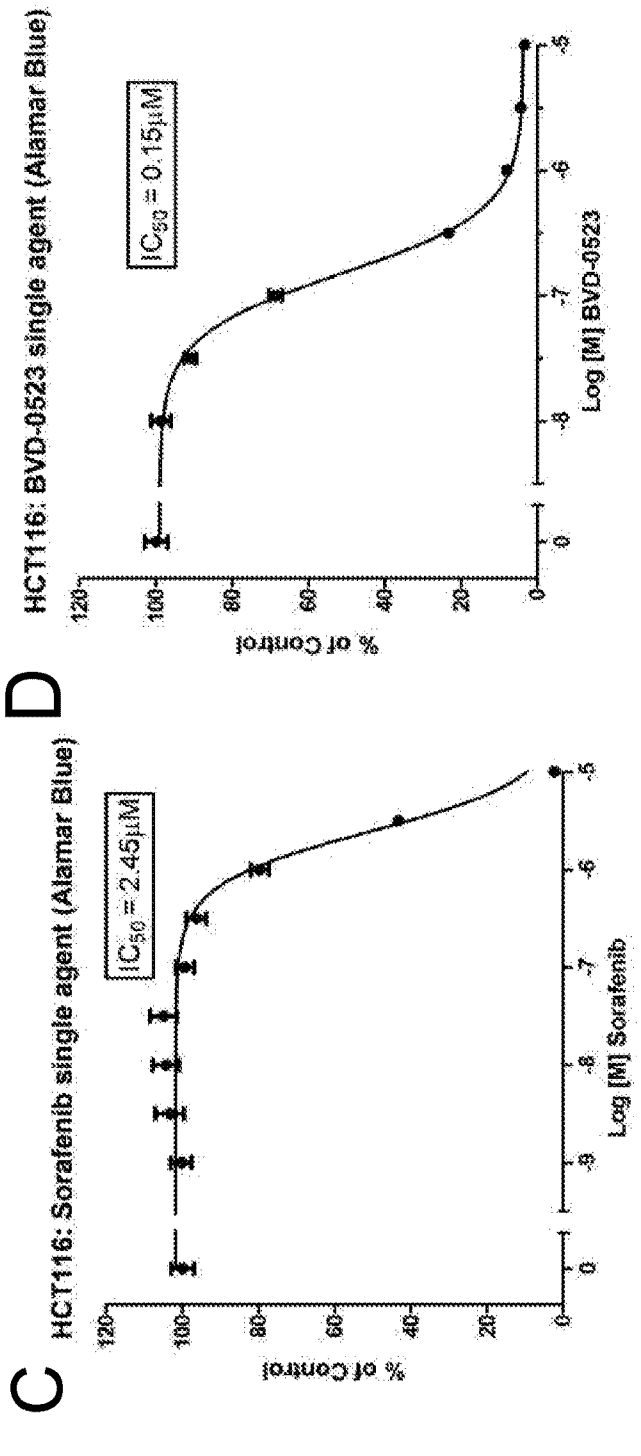


FIG. 34 Con't

HCT116: Sorafenib/BVD-523 Combination Assay – Alamar Blue

E

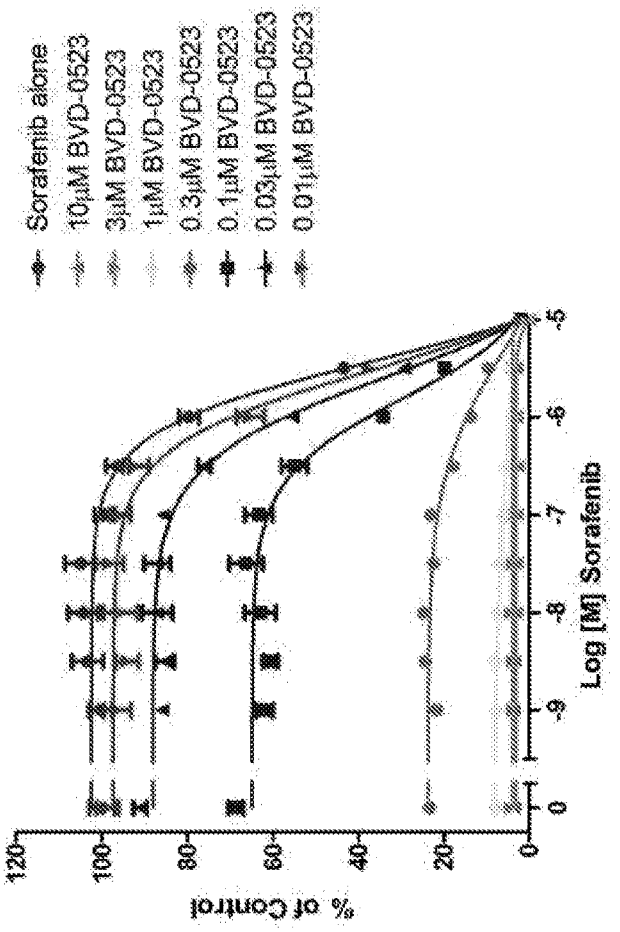


FIG. 35

HCT116: Dabrafenib/Trametinib Combination Assay – Alamar Blue

A

% Inhibition:

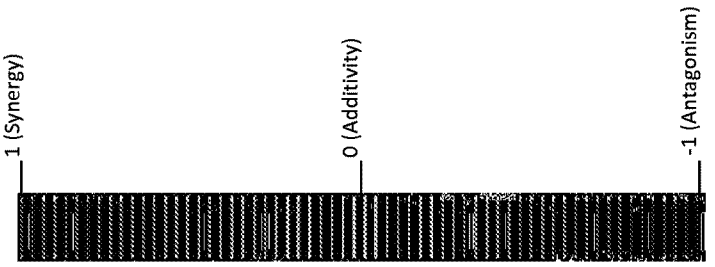
Trametinib (μM) \ Dabrafenib (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
0.1	94	94	93	92	92	93	96	98	98	98
0.03	87	87	85	83	79	82	91	97	93	96
0.01	77	77	71	66	58	61	77	92	87	96
0.003	56	52	48	44	36	35	50	79	82	94
0.001	30	28	26	21	15	18	32	63	82	85
0.0003	10	9	8	8	6	10	19	48	66	69
0.0001	7	4	0	-1	0	2	15	43	57	56
0	0	0	0	-1	2	3	9	43	53	52

FIG. 35 Con't

HCT116: Dabrafenib/Trametinib Combination Assay – Alamar Blue

B

Excess over Bliss:



Trametinib (μM) \ Dabrafenib (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
0.1	0.00 +/- 0.00	0.00 +/- 0.00	-0.01 +/- 0.00	-0.02 +/- 0.00	-0.03 +/- 0.00	-0.01 +/- 0.00	0.02 +/- 0.01	0.02 +/- 0.00	0.02 +/- 0.00	0.01 +/- 0.00
0.03	0.00 +/- 0.00	0.00 +/- 0.00	-0.02 +/- 0.00	-0.04 +/- 0.01	-0.08 +/- 0.01	-0.05 +/- 0.01	0.02 +/- 0.01	0.04 +/- 0.00	0.05 +/- 0.00	0.04 +/- 0.00
0.01	0.00 +/- 0.00	0.00 +/- 0.00	-0.06 +/- 0.02	-0.11 +/- 0.03	-0.19 +/- 0.04	-0.16 +/- 0.01	-0.02 +/- 0.01	0.05 +/- 0.01	0.08 +/- 0.01	0.09 +/- 0.01
0.003	0.00 +/- 0.00	-0.04 +/- 0.01	-0.08 +/- 0.04	-0.12 +/- 0.01	-0.21 +/- 0.03	-0.22 +/- 0.03	-0.10 +/- 0.03	0.04 +/- 0.01	0.13 +/- 0.03	0.15 +/- 0.01
0.001	0.00 +/- 0.00	-0.02 +/- 0.03	-0.04 +/- 0.07	-0.07 +/- 0.09	-0.16 +/- 0.06	-0.13 +/- 0.10	-0.04 +/- 0.08	0.03 +/- 0.02	0.15 +/- 0.05	0.19 +/- 0.03
0.0003	0.00 +/- 0.00	-0.01 +/- 0.03	-0.02 +/- 0.05	-0.01 +/- 0.03	-0.06 +/- 0.02	-0.03 +/- 0.04	0.01 +/- 0.01	-0.01 +/- 0.01	0.09 +/- 0.03	0.12 +/- 0.03
0.0001	0.00 +/- 0.00	-0.03 +/- 0.09	-0.07 +/- 0.10	-0.07 +/- 0.08	-0.09 +/- 0.08	-0.07 +/- 0.09	-0.01 +/- 0.05	-0.04 +/- 0.02	0.01 +/- 0.04	0.01 +/- 0.02
0	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

Trametinib (μM)

Dabrafenib (μM)

FIG. 35 Con't

HCT116: Dabrafenib/Trametinib Combination Assay – Alamar Blue

Single agent and Potentiation plots:

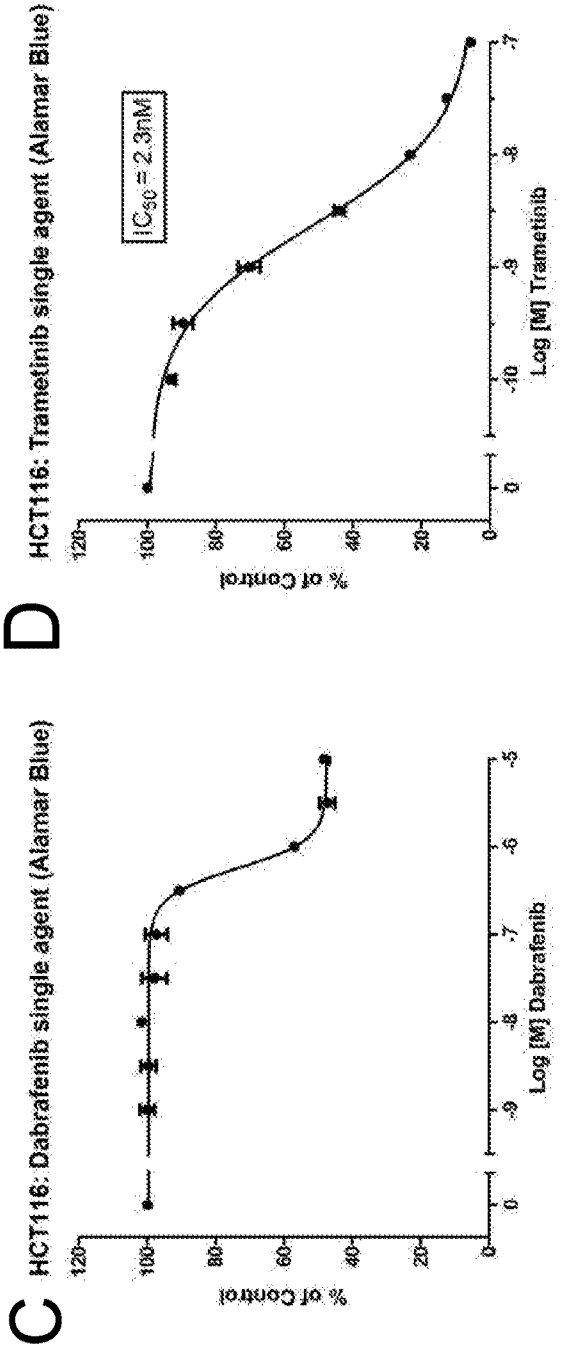


FIG. 35 Con't

HCT116: Dabrafenib/Trametinib Combination Assay – Alamar Blue

E

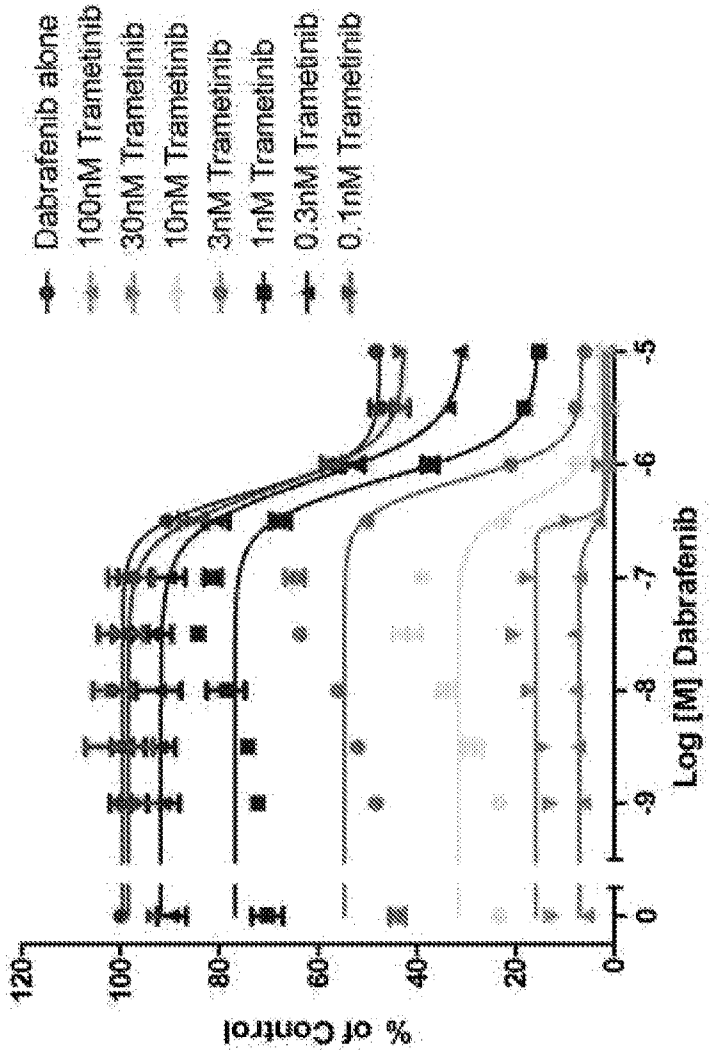


FIG. 36

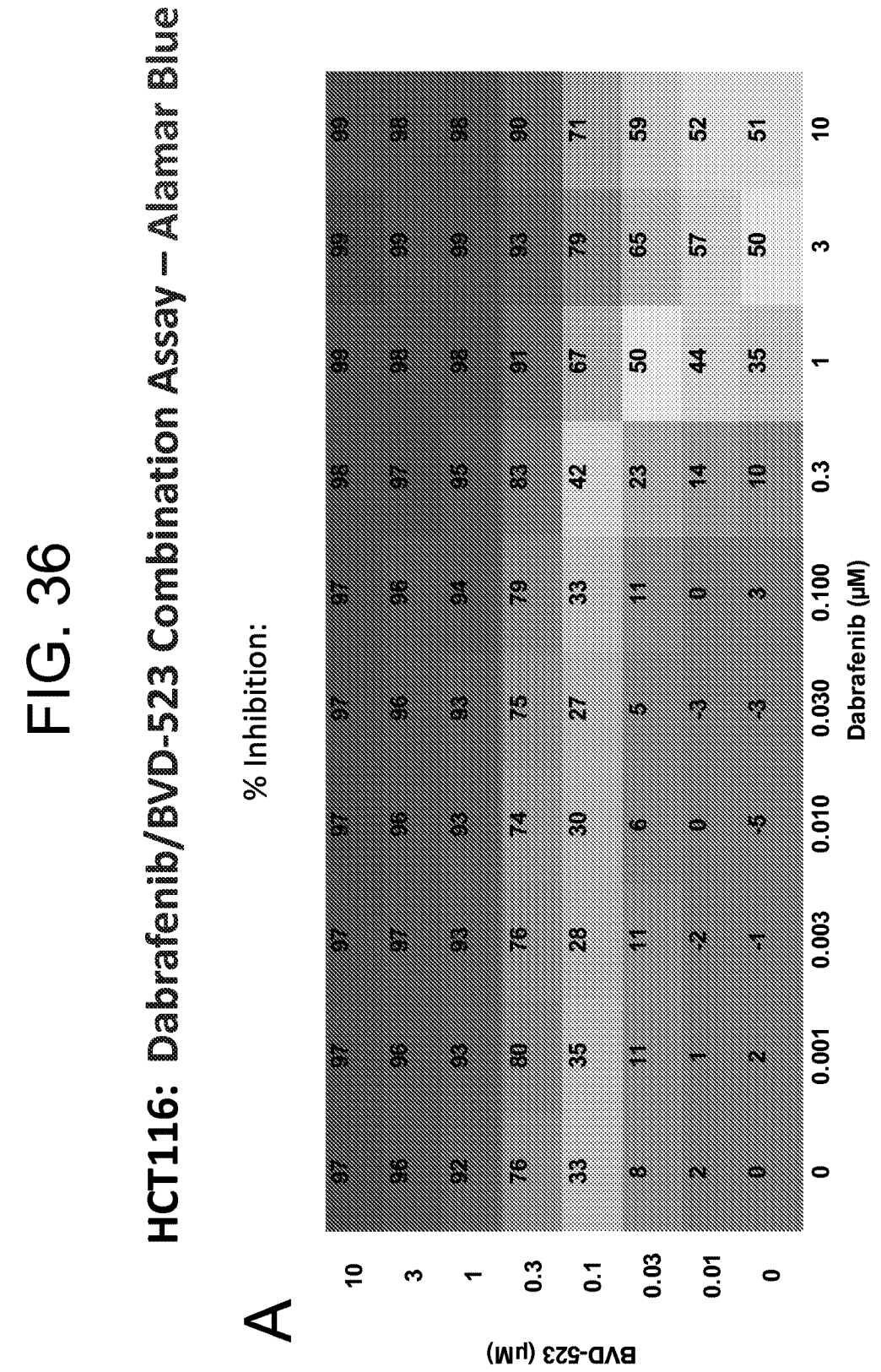

HCT116: Dabrafenib/BVD-523 Combination Assay – Alamar Blue
A
% Inhibition:
BVD-523 (μM)
10 97 97 97 97 97 97 98 98 99 99
3 96 96 97 96 96 96 97 98 98 98
1 92 93 93 93 93 94 95 96 96 96
0.3 76 80 76 74 75 79 83 91 93 90
0.1 33 35 28 30 27 33 42 67 79 71
0.03 8 11 11 6 5 11 23 50 65 59
0.01 2 1 -2 0 -3 0 14 44 57 52
0 0 2 -1 -5 -3 3 10 35 50 51
0 0.001 0.003 0.010 0.030 0.100 0.3 1 3 10
Dabrafenib (μM)

FIG. 36 Con't

HCT116: Dabrafenib/BVD-523 Combination Assay – Alamar Blue

B

Excess over Bliss:

BVD-523 (μM) \ Dabrafenib (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
10	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.01 +/- 0.00	0.01 +/- 0.00	0.01 +/- 0.00	0.01 +/- 0.00	0.01 +/- 0.00	0.01 +/- 0.00
3	0.00 +/- 0.00	0.00 +/- 0.00	0.01 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.01 +/- 0.01	0.01 +/- 0.00	0.01 +/- 0.00	0.01 +/- 0.00	0.00 +/- 0.00
1	0.00 +/- 0.00	0.01 +/- 0.01	0.01 +/- 0.01	0.01 +/- 0.00	0.02 +/- 0.01	0.03 +/- 0.00	0.03 +/- 0.00	0.03 +/- 0.00	0.03 +/- 0.00	0.01 +/- 0.01
0.3	0.00 +/- 0.00	0.04 +/- 0.03	0.00 +/- 0.01	0.01 +/- 0.01	0.03 +/- 0.03	0.05 +/- 0.02	0.06 +/- 0.00	0.06 +/- 0.00	0.05 +/- 0.01	0.02 +/- 0.01
0.1	0.00 +/- 0.00	0.00 +/- 0.02	-0.04 +/- 0.01	-0.04 +/- 0.05	-0.02 +/- 0.03	0.03 +/- 0.02	0.11 +/- 0.03	0.12 +/- 0.03	0.12 +/- 0.03	0.03 +/- 0.02
0.03	0.00 +/- 0.00	0.02 +/- 0.07	0.04 +/- 0.09	0.03 +/- 0.04	-0.01 +/- 0.06	0.00 +/- 0.06	0.06 +/- 0.06	0.10 +/- 0.04	0.10 +/- 0.05	0.04 +/- 0.00
0.01	0.00 +/- 0.00	-0.03 +/- 0.04	-0.03 +/- 0.05	0.03 +/- 0.01	-0.03 +/- 0.04	-0.05 +/- 0.04	0.02 +/- 0.09	0.07 +/- 0.03	0.06 +/- 0.02	0.00 +/- 0.03
0	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

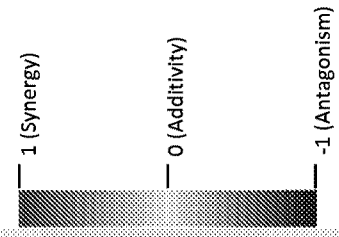


FIG. 36 Con't

HCT116: Dabrafenib/BVD-523 Combination Assay – Alamar Blue

Single agent and Potentiation plots:

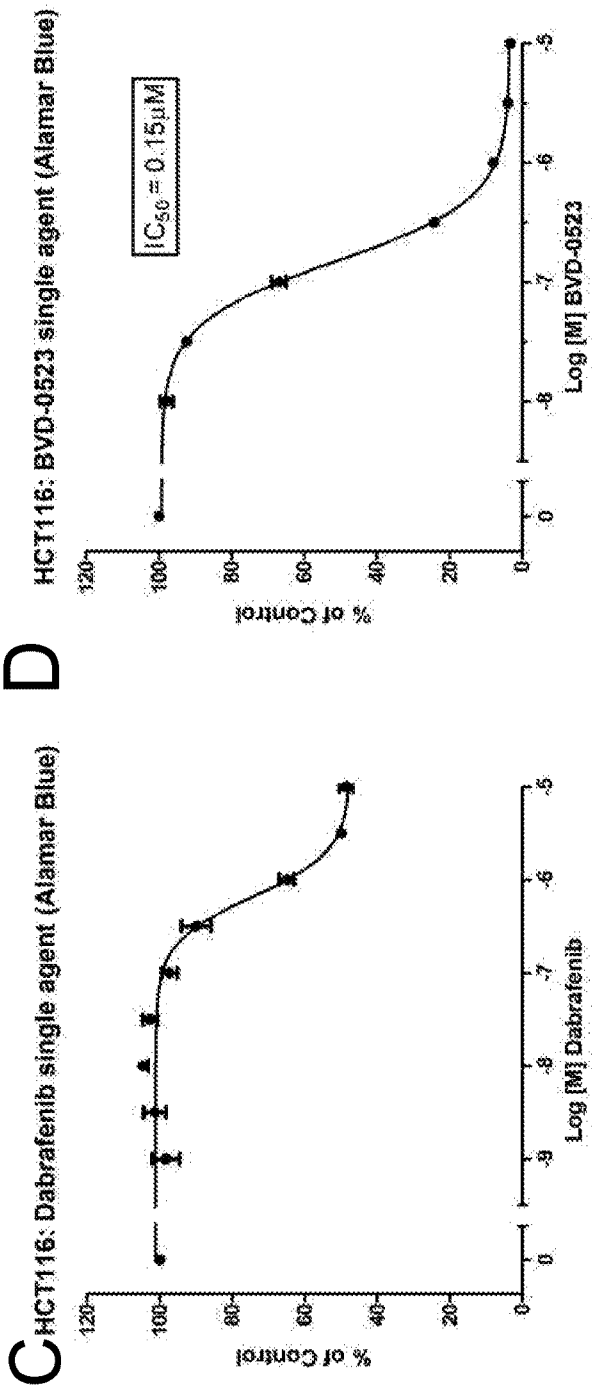


FIG. 36 Con't

HCT116: Dabrafenib/BVD-523 Combination Assay – Alamar Blue

E HCT116: Dabrafenib and BVD-0523 (Alamar Blue)

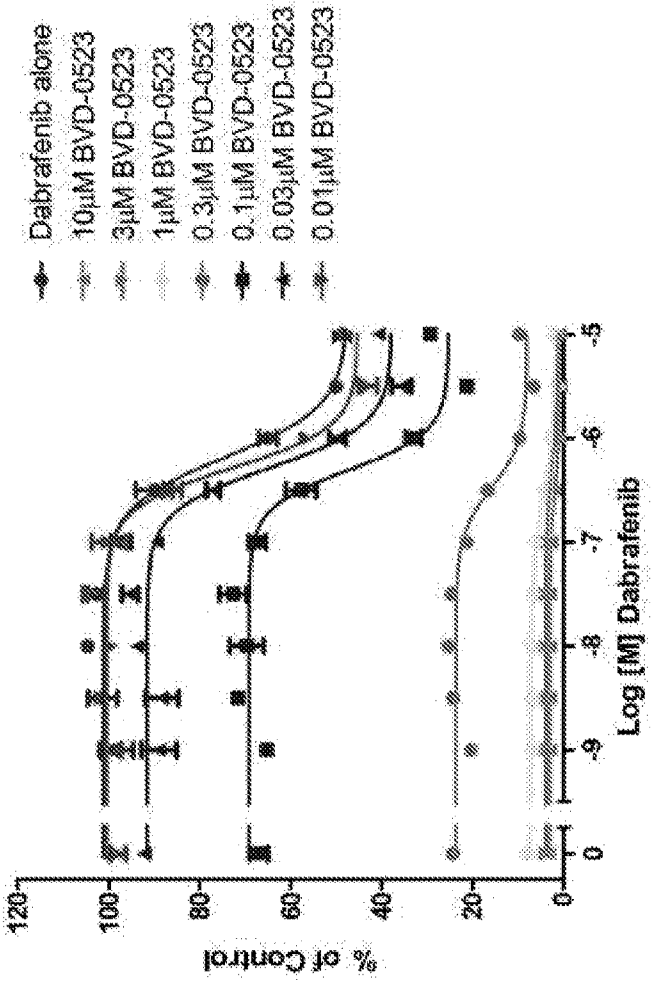


FIG. 37

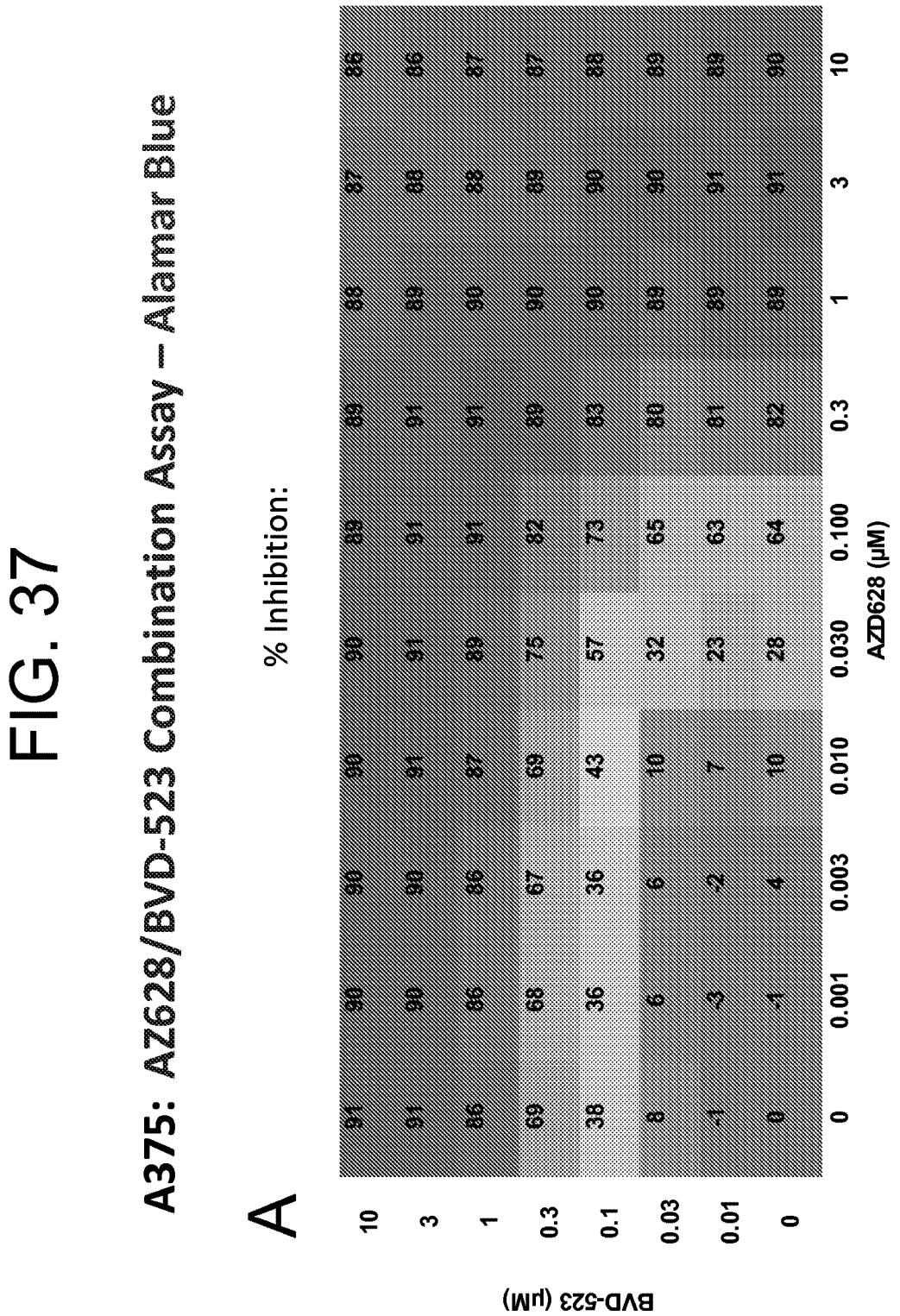

A375: AZ628/BVD-523 Combination Assay – Alamar Blue
A
% Inhibition:
BVD-523 (μM)
AZD628 (μM)
10 3 1 0.3 0.1 0.03 0.01 0
0 0.001 0.003 0.010 0.030 0.100 0.3 1 3 10
91 91 86 69 38 8 -1 0
90 90 86 68 36 6 -3 -1
90 90 86 67 36 6 -2 4
90 91 87 69 43 10 7 10
90 91 91 75 57 32 23 28
89 91 91 82 73 65 63 64
89 91 91 89 83 80 81 82
89 89 90 90 90 89 89 88
87 88 88 89 90 90 91 91
86 86 87 87 88 89 89 90

FIG. 37 Con't

A375: AZ628/BVD-523 Combination Assay – Alamar Blue

B

Excess over Bliss:

BVD-523 (μM) \ AZD628 (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
10	0.00 +/- 0.00	-0.01 +/- 0.01	-0.01 +/- 0.01	-0.02 +/- 0.01	-0.04 +/- 0.01	-0.07 +/- 0.00	-0.09 +/- 0.00	-0.11 +/- 0.00	-0.12 +/- 0.01	-0.13 +/- 0.01
3	0.00 +/- 0.00	-0.01 +/- 0.00	-0.01 +/- 0.01	-0.01 +/- 0.01	-0.02 +/- 0.01	-0.06 +/- 0.00	-0.08 +/- 0.00	-0.10 +/- 0.01	-0.11 +/- 0.00	-0.13 +/- 0.01
1	0.00 +/- 0.00	0.00 +/- 0.01	-0.01 +/- 0.00	0.00 +/- 0.00	-0.02 +/- 0.00	-0.04 +/- 0.00	-0.06 +/- 0.01	-0.09 +/- 0.01	-0.11 +/- 0.01	-0.12 +/- 0.01
0.3	0.00 +/- 0.00	-0.01 +/- 0.02	-0.04 +/- 0.01	-0.03 +/- 0.02	-0.03 +/- 0.01	-0.07 +/- 0.00	-0.05 +/- 0.00	-0.07 +/- 0.01	-0.09 +/- 0.01	-0.10 +/- 0.01
0.1	0.00 +/- 0.00	-0.02 +/- 0.04	-0.04 +/- 0.04	-0.01 +/- 0.03	0.02 +/- 0.03	-0.05 +/- 0.01	-0.05 +/- 0.00	-0.03 +/- 0.01	-0.05 +/- 0.00	-0.06 +/- 0.00
0.03	0.00 +/- 0.00	-0.02 +/- 0.05	-0.06 +/- 0.03	-0.07 +/- 0.04	-0.02 +/- 0.03	-0.01 +/- 0.02	-0.03 +/- 0.00	-0.02 +/- 0.00	-0.02 +/- 0.00	-0.02 +/- 0.00
0.01	0.00 +/- 0.00	-0.01 +/- 0.04	-0.05 +/- 0.04	-0.02 +/- 0.04	-0.04 +/- 0.06	0.00 +/- 0.02	-0.01 +/- 0.01	0.00 +/- 0.00	0.00 +/- 0.00	-0.01 +/- 0.01
0	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

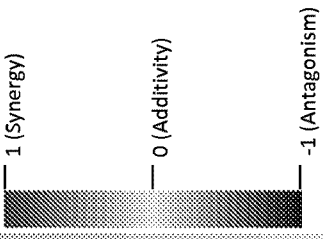


FIG. 37 Con't

A375: AZ628/BVD-523 Combination Assay – Alamar Blue

Single agent and Potentiation plots:

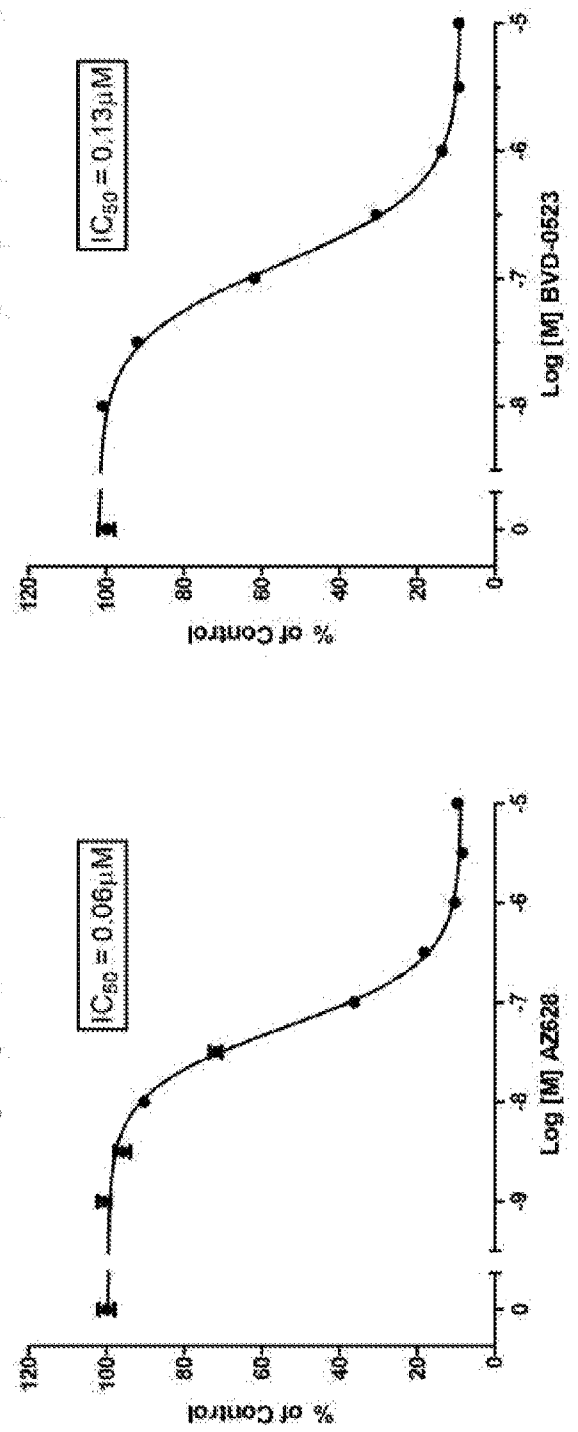


FIG. 37 Con't

A375: AZ628/BVD-523 Combination Assay – Alamar Blue

E

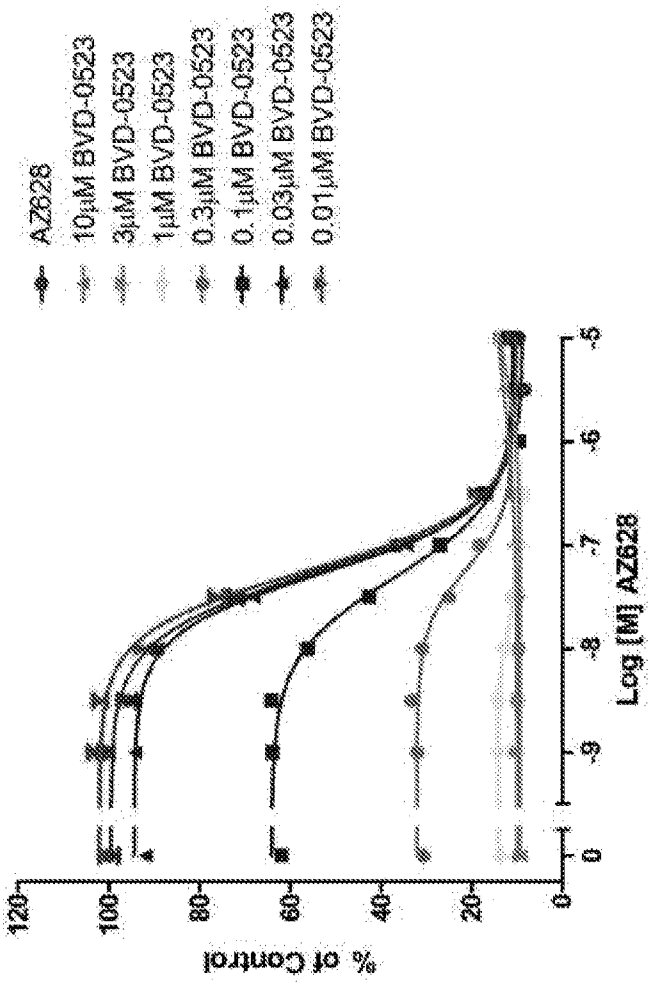


FIG. 38

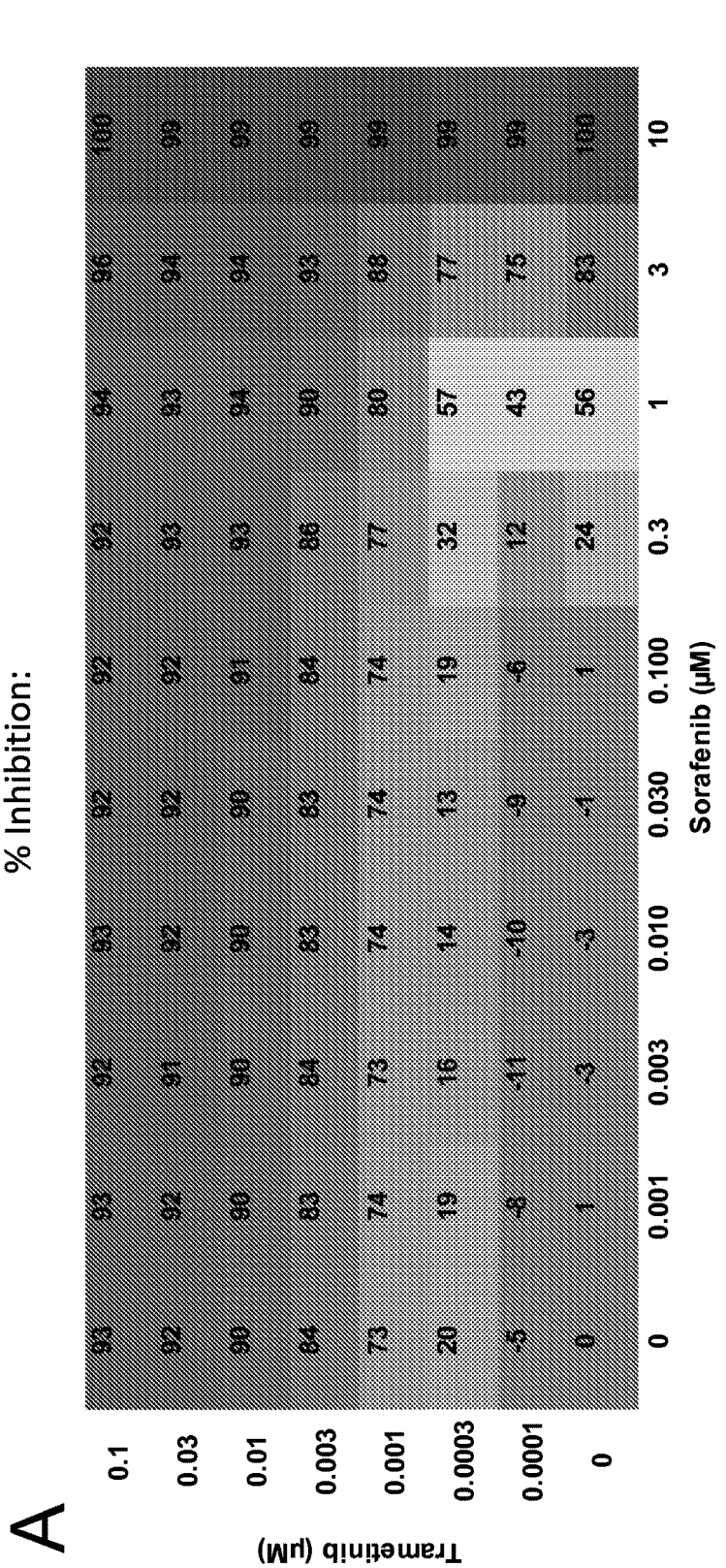

A375: Sorafenib/Trametinib Combination Assay – Alamar Blue
% Inhibition:
A
Trametinib (μM)
Sorafenib (μM)
0.1 93 93 92 93 92 92 92 94 96 100
0.03 92 92 91 92 92 92 93 93 94 99
0.01 90 90 90 90 90 91 93 94 94 99
0.003 84 83 84 83 83 84 86 90 93 99
0.001 73 74 73 74 74 74 77 80 88 99
0.0003 20 19 16 14 13 19 32 57 77 98
0.0001 -5 -8 -11 -10 -9 -6 12 43 75 99
0 0 1 -2 -3 -1 1 24 56 83 100
0 0.001 0.003 0.010 0.030 0.100 0.3 1 3 10

FIG. 38 Con't

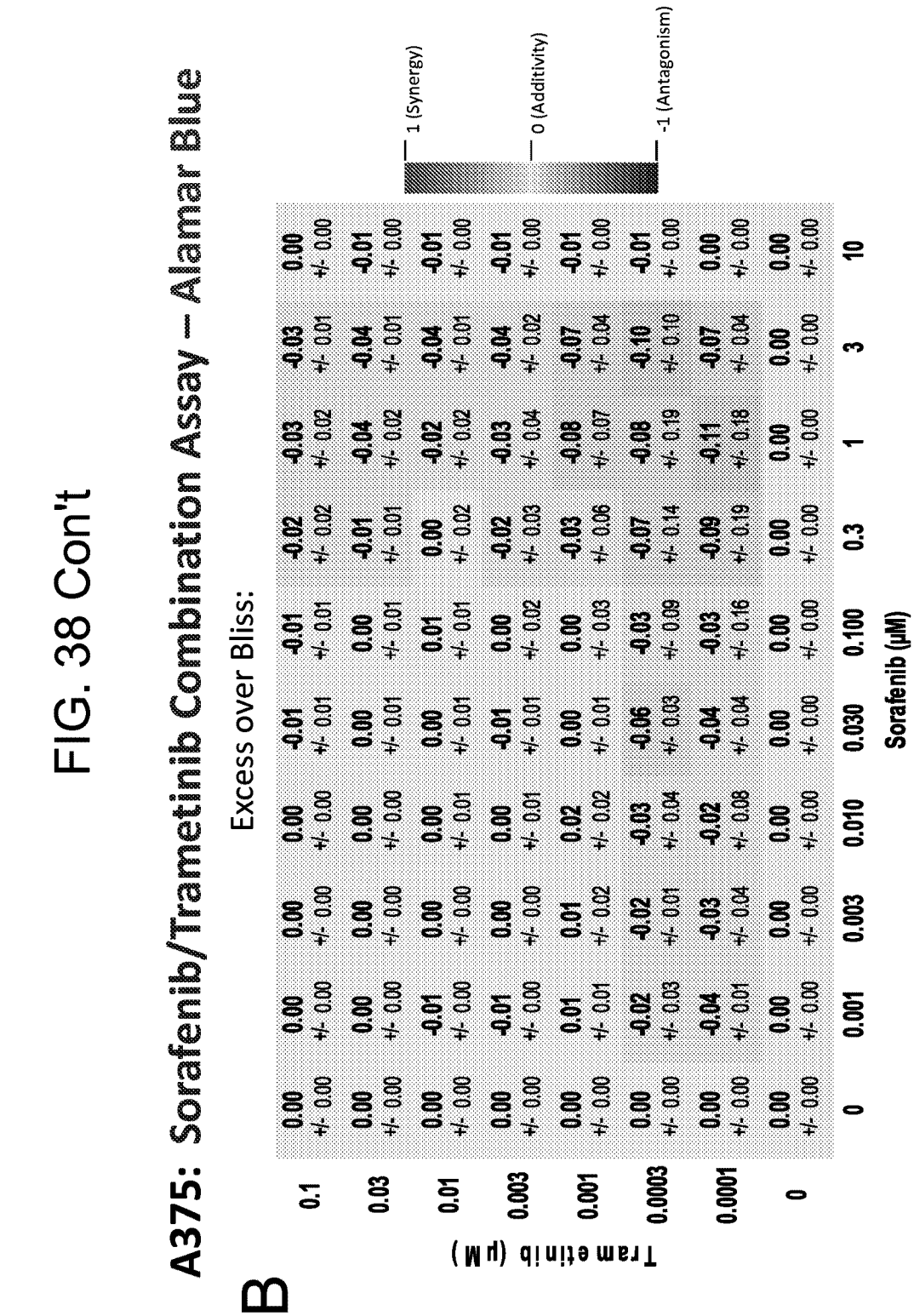

A375: Sorafenib/Trametinib Combination Assay – Alamar Blue
B
Excess over Bliss:
1 (Synergy)
0 (Additivity)
-1 (Antagonism)
Trametinib (μM)
Sorafenib (μM)
0.1
0.03
0.01
0.003
0.001
0.0003
0.0001
0
0 0.001 0.003 0.010 0.030 0.100 0.3 1 3 10
0.00 +/- 0.00 0.00 +/- 0.00 0.00 +/- 0.00 -0.01 +/- 0.01 -0.01 +/- 0.01 -0.02 +/- 0.02 -0.03 +/- 0.02 -0.03 +/- 0.01 0.00 +/- 0.00
0.00 +/- 0.00 0.00 +/- 0.00 0.00 +/- 0.00 0.00 +/- 0.01 0.00 +/- 0.01 -0.01 +/- 0.01 -0.04 +/- 0.02 -0.04 +/- 0.01 -0.01 +/- 0.00
0.00 +/- 0.00 -0.01 +/- 0.00 0.00 +/- 0.01 0.00 +/- 0.01 0.01 +/- 0.01 0.00 +/- 0.02 -0.02 +/- 0.02 -0.04 +/- 0.01 -0.01 +/- 0.00
0.00 +/- 0.00 -0.01 +/- 0.00 0.00 +/- 0.01 -0.01 +/- 0.01 0.00 +/- 0.02 -0.02 +/- 0.03 -0.03 +/- 0.04 -0.04 +/- 0.02 -0.01 +/- 0.00
0.00 +/- 0.00 0.01 +/- 0.01 0.01 +/- 0.02 0.02 +/- 0.02 0.00 +/- 0.01 0.00 +/- 0.03 -0.03 +/- 0.06 -0.08 +/- 0.07 -0.07 +/- 0.04 -0.01 +/- 0.00
0.00 +/- 0.00 -0.02 +/- 0.03 -0.02 +/- 0.01 -0.03 +/- 0.04 -0.06 +/- 0.03 -0.03 +/- 0.09 -0.07 +/- 0.14 -0.08 +/- 0.19 -0.10 +/- 0.10 -0.01 +/- 0.00
0.00 +/- 0.00 -0.04 +/- 0.01 -0.03 +/- 0.04 -0.02 +/- 0.08 -0.04 +/- 0.04 -0.03 +/- 0.16 -0.09 +/- 0.19 -0.11 +/- 0.18 -0.07 +/- 0.04 0.00 +/- 0.00
0.00 +/- 0.00 0.00 +/- 0.00 0.00 +/- 0.00 0.00 +/- 0.00 0.00 +/- 0.00 0.00 +/- 0.00 0.00 +/- 0.00 0.00 +/- 0.00 0.00 +/- 0.00 0.00 +/- 0.00

FIG. 38 Con't

A375: Sorafenib/Trametinib Combination Assay – Alamar Blue

Single agent and Potentiation plots:

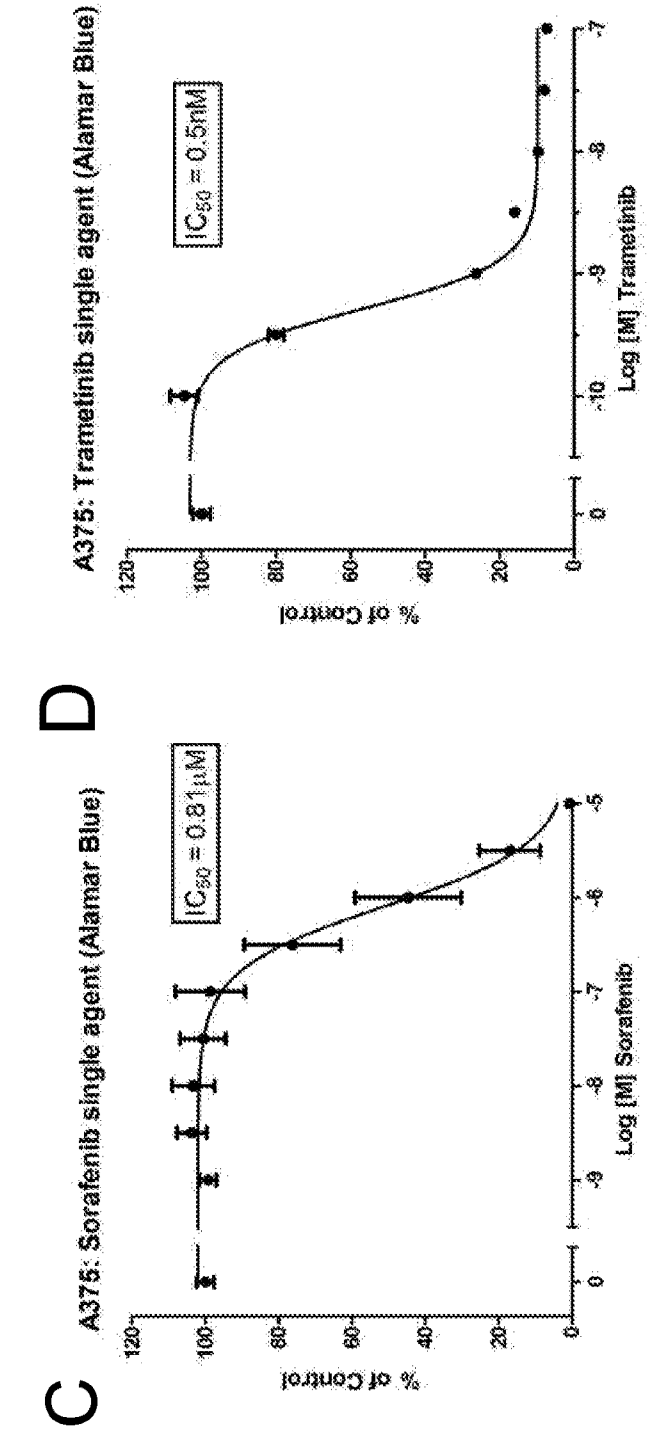


FIG. 38 Con't

A375: Sorafenib/Trametinib Combination Assay – Alamar Blue

E A375: Sorafenib and Trametinib (Alamar Blue)

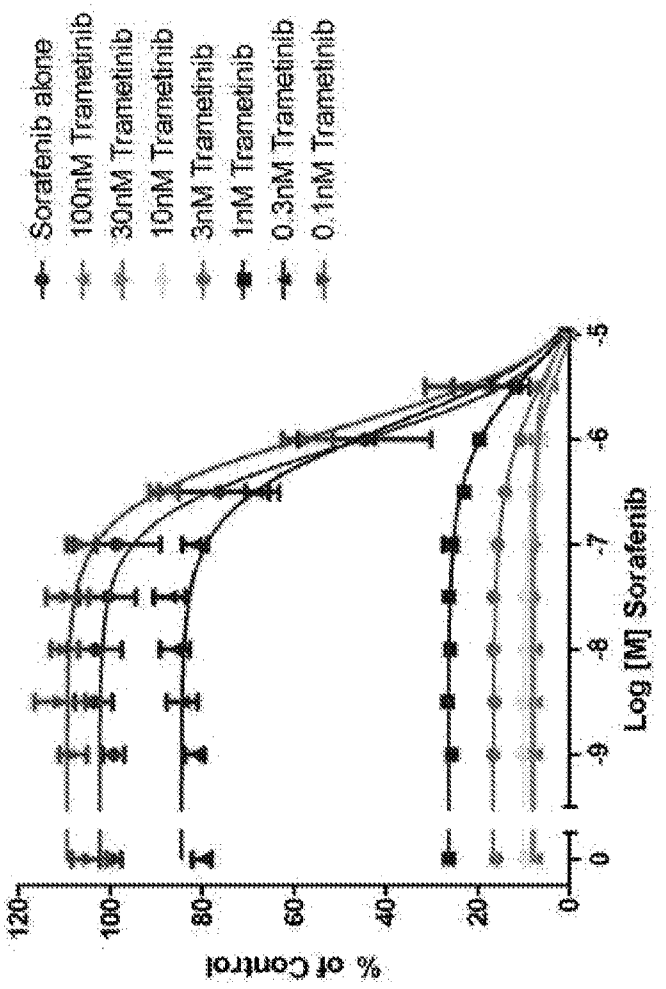


FIG. 39

A375: Sorafenib/BVD-523 Combination Assay – Alamar Blue

% Inhibition:

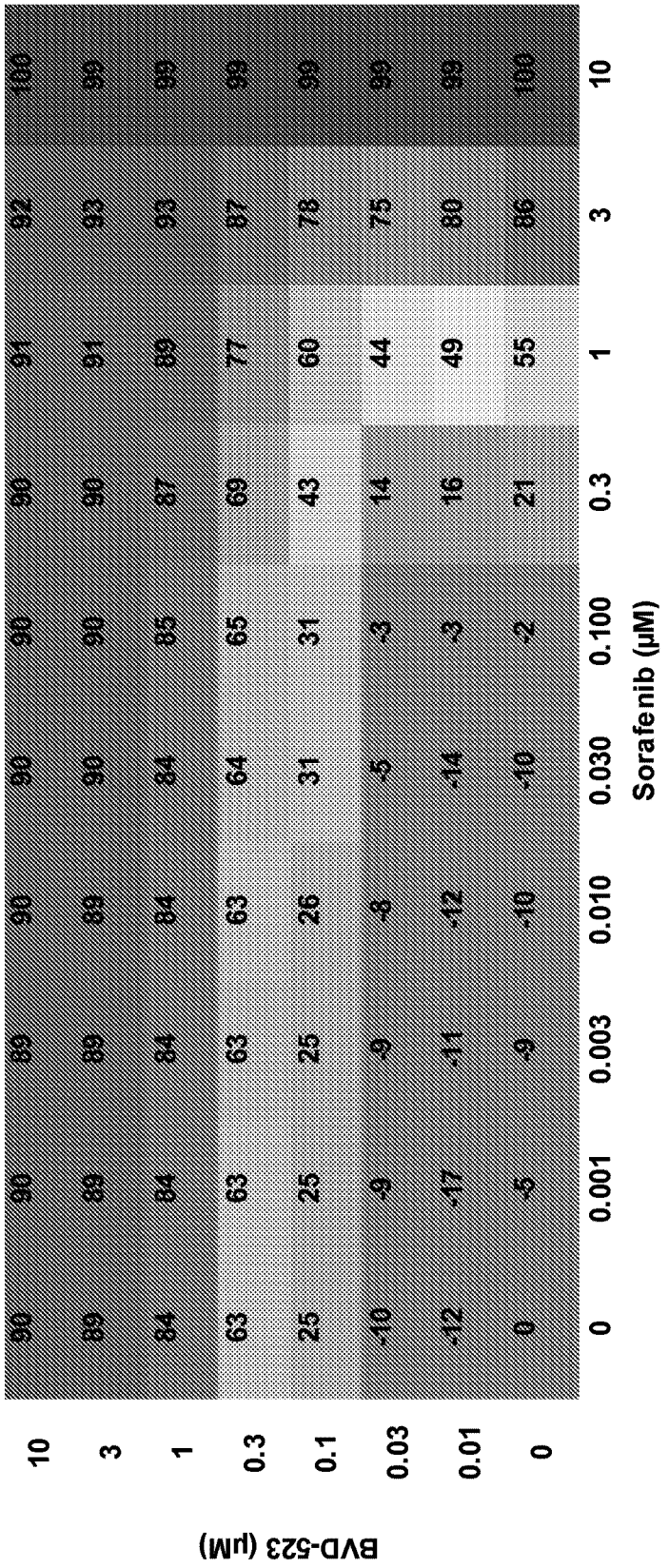


FIG. 39 Con't

A375: Sorafenib/BVD-523 Combination Assay – Alamar Blue

B

Excess over Bliss:

BVD-523 (μM) \ Sorafenib (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
10	0.00 +/- 0.00	0.01 +/- 0.00	0.00 +/- 0.01	0.01 +/- 0.00	0.01 +/- 0.00	0.00 +/- 0.00	-0.02 +/- 0.01	-0.05 +/- 0.02	-0.07 +/- 0.02	0.00 +/- 0.00
3	0.00 +/- 0.00	0.00 +/- 0.00	0.01 +/- 0.01	0.01 +/- 0.00	0.02 +/- 0.00	0.01 +/- 0.00	-0.01 +/- 0.01	-0.04 +/- 0.02	-0.06 +/- 0.02	-0.01 +/- 0.00
1	0.00 +/- 0.00	0.00 +/- 0.01	0.01 +/- 0.01	0.01 +/- 0.01	0.01 +/- 0.01	0.01 +/- 0.01	-0.01 +/- 0.01	-0.04 +/- 0.02	-0.05 +/- 0.02	-0.01 +/- 0.00
0.3	0.00 +/- 0.00	0.02 +/- 0.02	0.04 +/- 0.03	0.04 +/- 0.02	0.05 +/- 0.00	0.03 +/- 0.02	-0.01 +/- 0.00	-0.06 +/- 0.04	-0.07 +/- 0.05	-0.01 +/- 0.00
0.1	0.00 +/- 0.00	0.04 +/- 0.01	0.07 +/- 0.05	0.08 +/- 0.03	0.14 +/- 0.01	0.07 +/- 0.04	0.02 +/- 0.02	-0.06 +/- 0.11	-0.11 +/- 0.10	0.00 +/- 0.00
0.03	0.00 +/- 0.00	0.07 +/- 0.02	0.11 +/- 0.06	0.13 +/- 0.03	0.17 +/- 0.02	0.09 +/- 0.05	0.01 +/- 0.02	-0.06 +/- 0.15	-0.10 +/- 0.17	0.00 +/- 0.00
0.01	0.00 +/- 0.00	0.00 +/- 0.05	0.12 +/- 0.11	0.11 +/- 0.04	0.09 +/- 0.05	0.10 +/- 0.07	0.04 +/- 0.08	0.00 +/- 0.06	-0.05 +/- 0.12	0.00 +/- 0.00
0	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

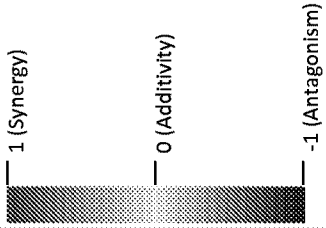


FIG. 39 Con't

A375: Sorafenib/BVD-523 Combination Assay – Alamar Blue

Single agent and Potentiation plots:

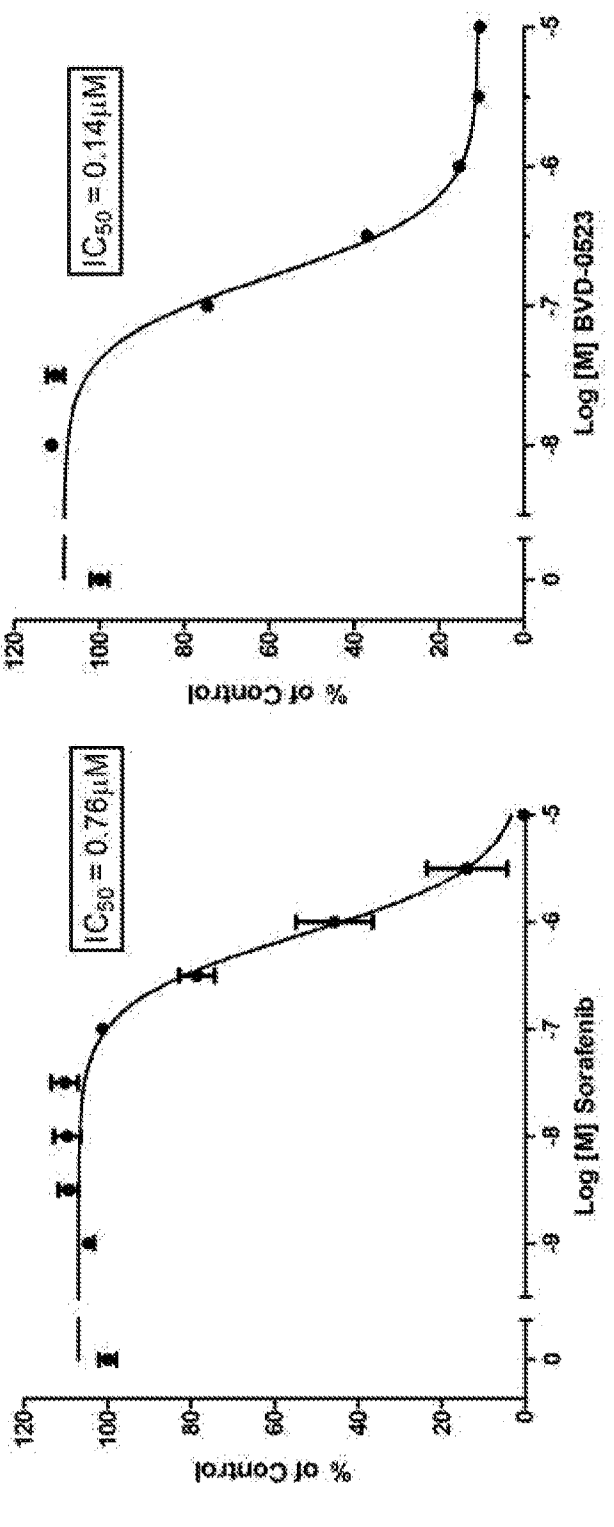


FIG. 39 Con't

A375: Sorafenib/BVD-523 Combination Assay – Alamar Blue

E

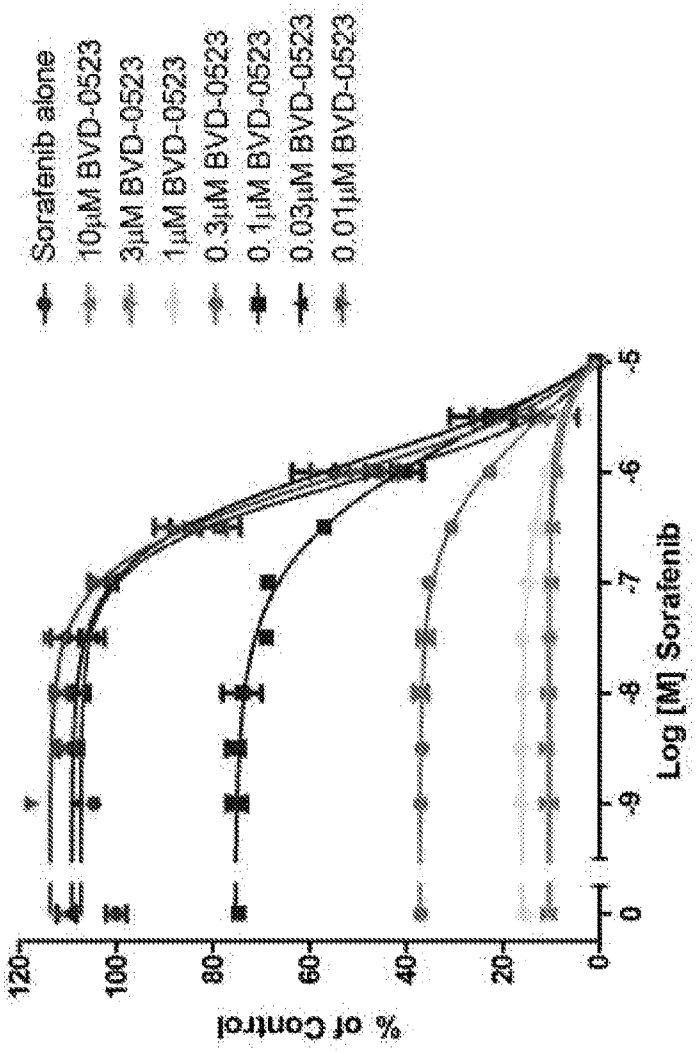


FIG. 40

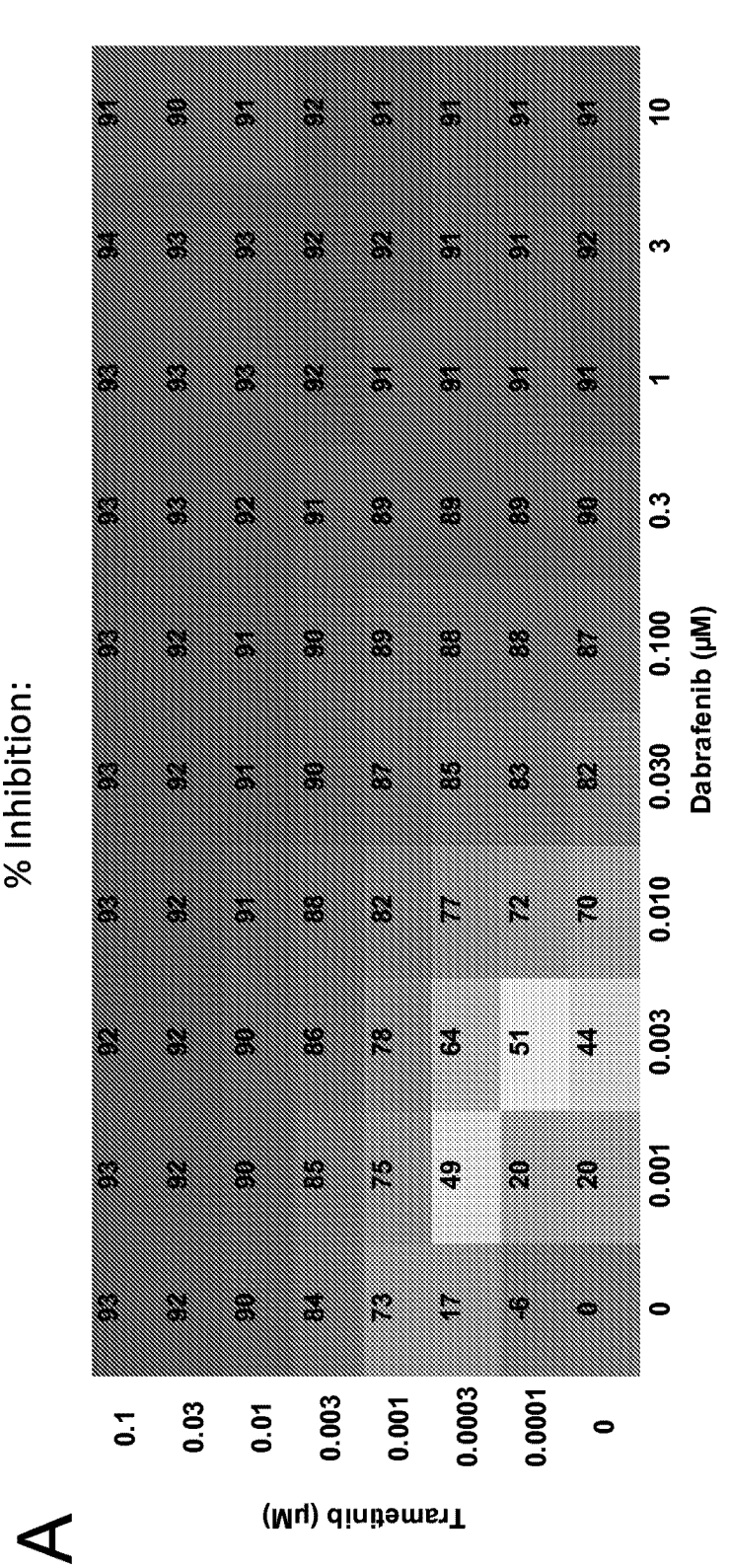

A
A375: Dabrafenib/Trametinib Combination Assay – Alamar Blue
% Inhibition:
Trametinib (μM)
0.1
0.03
0.01
0.003
0.001
0.0003
0.0001
0
93 93 92 93 93 93 93 93 94 91
92 92 92 92 92 93 93 93 93 90
90 90 90 91 91 92 93 93 93 91
84 85 86 88 90 91 92 92 92 92
73 75 78 82 87 89 89 91 92 91
17 49 64 77 85 88 89 91 91 91
-6 20 51 72 83 88 89 91 91 91
0 20 44 70 82 87 90 91 92 91
0 0.001 0.003 0.010 0.030 0.100 0.3 1 3 10
Dabrafenib (μM)

FIG. 40 Con't

A375: Dabrafenib/Trametinib Combination Assay – Alamar Blue

B

Excess over Bliss:

Trametinib (μM) \ Dabrafenib (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
0.1	0.00 +/- 0.00	-0.02 +/- 0.00	-0.04 +/- 0.00	-0.05 +/- 0.00	-0.06 +/- 0.01	-0.06 +/- 0.01	-0.06 +/- 0.00	-0.06 +/- 0.00	-0.06 +/- 0.01	-0.09 +/- 0.00
0.03	0.00 +/- 0.00	-0.02 +/- 0.00	-0.04 +/- 0.00	-0.06 +/- 0.00	-0.07 +/- 0.00	-0.07 +/- 0.00	-0.06 +/- 0.00	-0.06 +/- 0.00	-0.06 +/- 0.00	-0.09 +/- 0.01
0.01	0.00 +/- 0.00	-0.02 +/- 0.00	-0.04 +/- 0.01	-0.06 +/- 0.00	-0.07 +/- 0.00	-0.07 +/- 0.00	-0.06 +/- 0.00	-0.06 +/- 0.00	-0.06 +/- 0.00	-0.09 +/- 0.00
0.003	0.00 +/- 0.00	-0.03 +/- 0.00	-0.05 +/- 0.00	-0.07 +/- 0.01	-0.07 +/- 0.00	-0.08 +/- 0.00	-0.07 +/- 0.00	-0.06 +/- 0.00	-0.06 +/- 0.00	-0.07 +/- 0.00
0.001	0.00 +/- 0.00	-0.03 +/- 0.01	-0.07 +/- 0.01	-0.10 +/- 0.01	-0.09 +/- 0.00	-0.08 +/- 0.01	-0.08 +/- 0.01	-0.07 +/- 0.01	-0.06 +/- 0.00	-0.06 +/- 0.01
0.0003	0.00 +/- 0.00	0.16 +/- 0.02	0.11 +/- 0.05	0.02 +/- 0.04	0.00 +/- 0.02	-0.02 +/- 0.01	-0.02 +/- 0.01	-0.02 +/- 0.01	-0.02 +/- 0.01	-0.02 +/- 0.01
0.0001	0.00 +/- 0.00	0.05 +/- 0.03	0.10 +/- 0.04	0.04 +/- 0.02	0.02 +/- 0.02	0.01 +/- 0.00	0.00 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.00	0.00 +/- 0.01
0	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

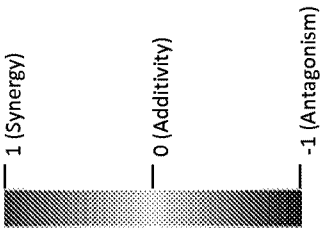


FIG. 40 Con't

A375: Dabrafenib/Trametinib Combination Assay – Alamar Blue

Single agent and Potentiation plots:

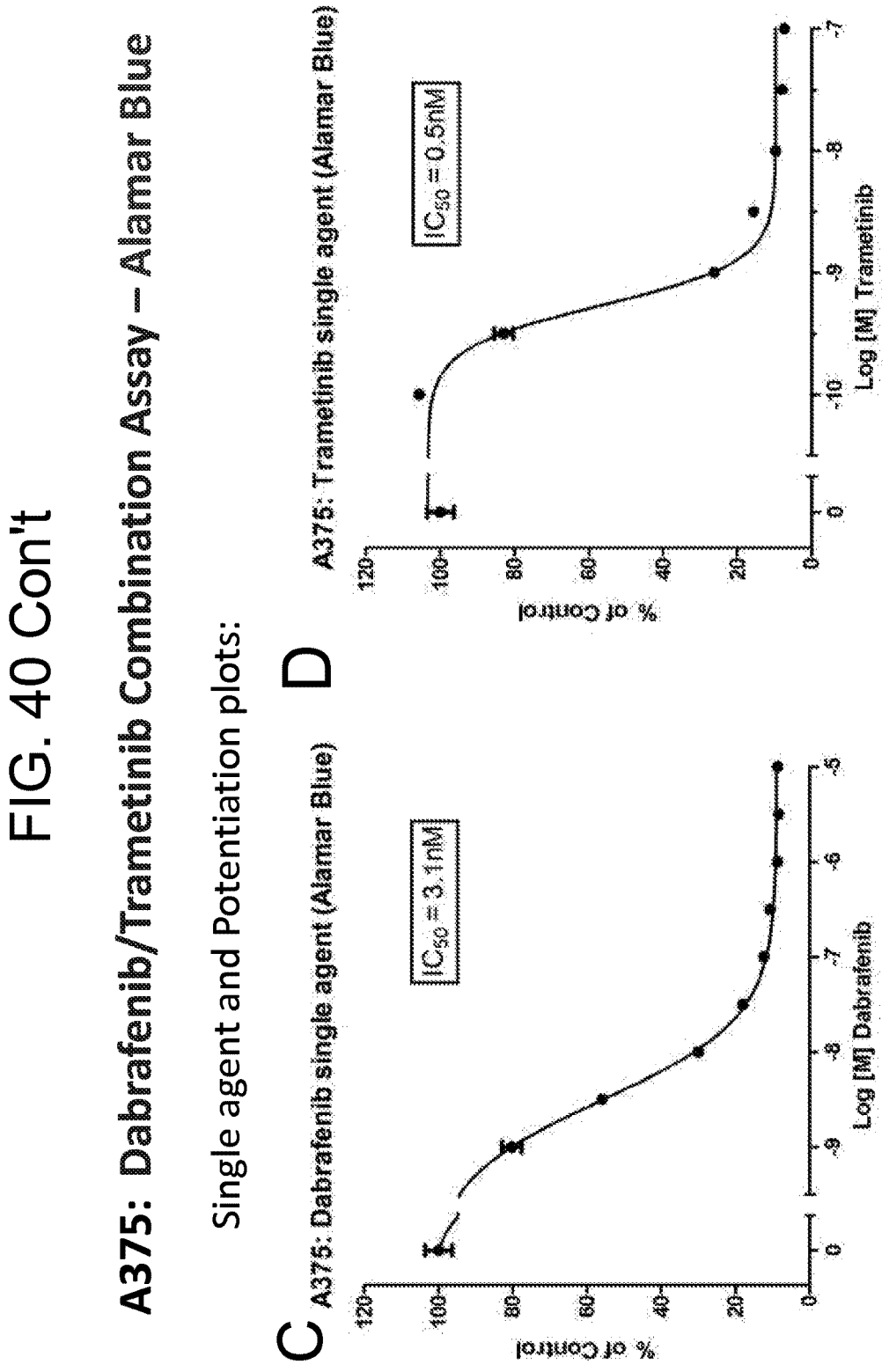


FIG. 40 Con't

A375: Dabrafenib/Trametinib Combination Assay – Alamar Blue

E

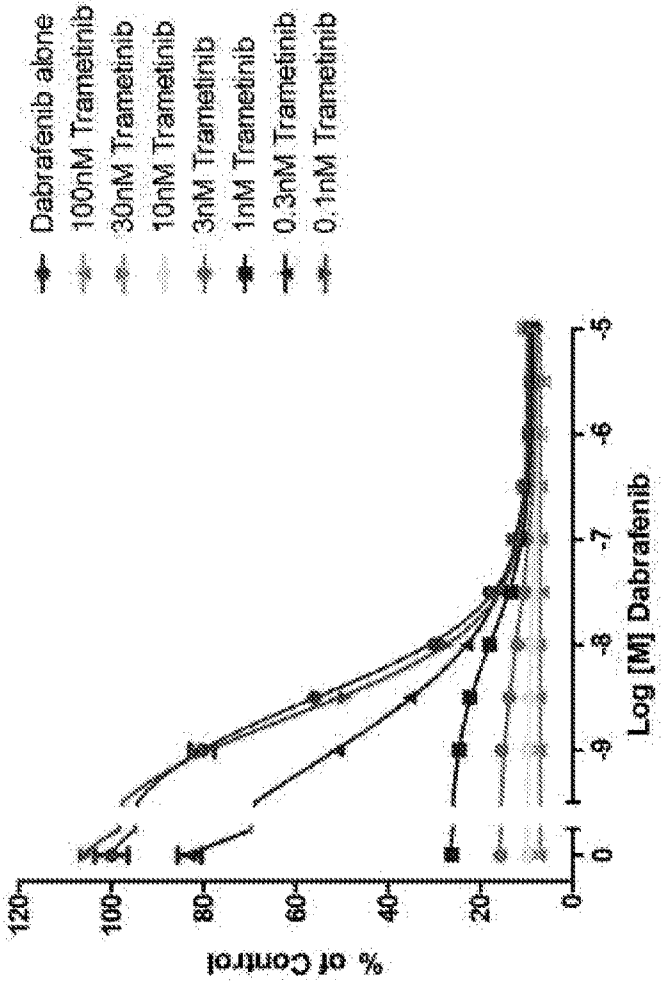


FIG. 41

A

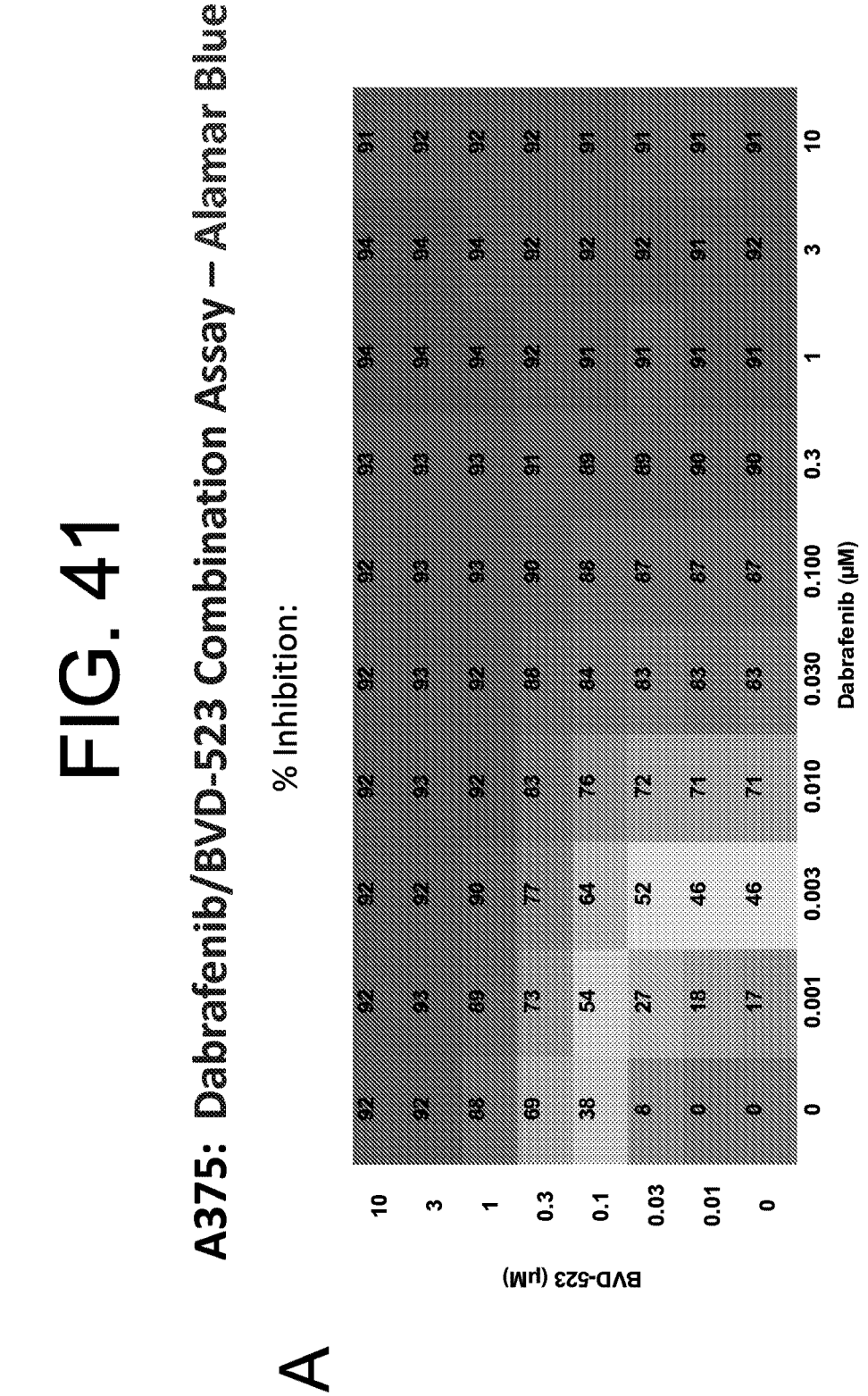

A375: Dabrafenib/BVD-523 Combination Assay – Alamar Blue
% Inhibition:
BVD-523 (μM)
10 92 92 92 92 92 92 93 93 94 94 91
3 92 93 92 93 93 93 93 93 94 94 92
1 88 89 90 92 92 93 93 94 92 92 92
0.3 69 73 77 83 86 90 91 91 92 92 92
0.1 38 54 64 76 84 88 89 89 92 92 91
0.03 6 27 52 72 83 87 89 89 91 92 91
0.01 0 18 46 71 83 87 90 91 91 91 91
0 0 17 46 71 83 87 90 91 92 92 91
0 0.001 0.003 0.010 0.030 0.100 0.3 1 3 10
Dabrafenib (μM)

FIG. 41 Con't

A375: Dabrafenib/BVD-523 Combination Assay – Alamar Blue

B

Excess over Bliss:

BVD-523 (μM) \ Dabrafenib (μM)	0	0.001	0.003	0.010	0.030	0.100	0.3	1	3	10
10	0.00 +/- 0.00	-0.02 +/- 0.00	-0.04 +/- 0.00	-0.06 +/- 0.00	-0.06 +/- 0.00	-0.07 +/- 0.00	-0.06 +/- 0.00	-0.05 +/- 0.00	-0.05 +/- 0.00	-0.08 +/- 0.00
3	0.00 +/- 0.00	-0.01 +/- 0.00	-0.04 +/- 0.00	-0.05 +/- 0.00	-0.06 +/- 0.00	-0.06 +/- 0.01	-0.06 +/- 0.01	-0.05 +/- 0.01	-0.05 +/- 0.01	-0.08 +/- 0.00
1	0.00 +/- 0.00	0.00 +/- 0.01	-0.03 +/- 0.00	-0.05 +/- 0.00	-0.05 +/- 0.00	-0.06 +/- 0.00	-0.06 +/- 0.00	-0.05 +/- 0.01	-0.05 +/- 0.00	-0.07 +/- 0.00
0.3	0.00 +/- 0.00	-0.01 +/- 0.02	-0.06 +/- 0.01	-0.08 +/- 0.00	-0.07 +/- 0.00	-0.06 +/- 0.00	-0.06 +/- 0.00	-0.05 +/- 0.00	-0.05 +/- 0.00	-0.05 +/- 0.00
0.1	0.00 +/- 0.00	0.05 +/- 0.03	-0.02 +/- 0.01	-0.05 +/- 0.01	-0.05 +/- 0.01	-0.04 +/- 0.01	-0.04 +/- 0.01	-0.03 +/- 0.01	-0.03 +/- 0.01	-0.03 +/- 0.00
0.03	0.00 +/- 0.00	0.03 +/- 0.04	0.02 +/- 0.02	-0.01 +/- 0.02	-0.01 +/- 0.01	-0.01 +/- 0.00	-0.01 +/- 0.00	-0.01 +/- 0.00	-0.01 +/- 0.01	-0.01 +/- 0.01
0.01	0.00 +/- 0.00	0.01 +/- 0.06	0.00 +/- 0.02	0.01 +/- 0.01	0.00 +/- 0.01	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.01	0.00 +/- 0.00	0.00 +/- 0.00
0	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00	0.00 +/- 0.00

FIG. 41 Con't

A375: Dabrafenib/BVD-523 Combination Assay – Alamar Blue

Single agent and Potentiation plots:

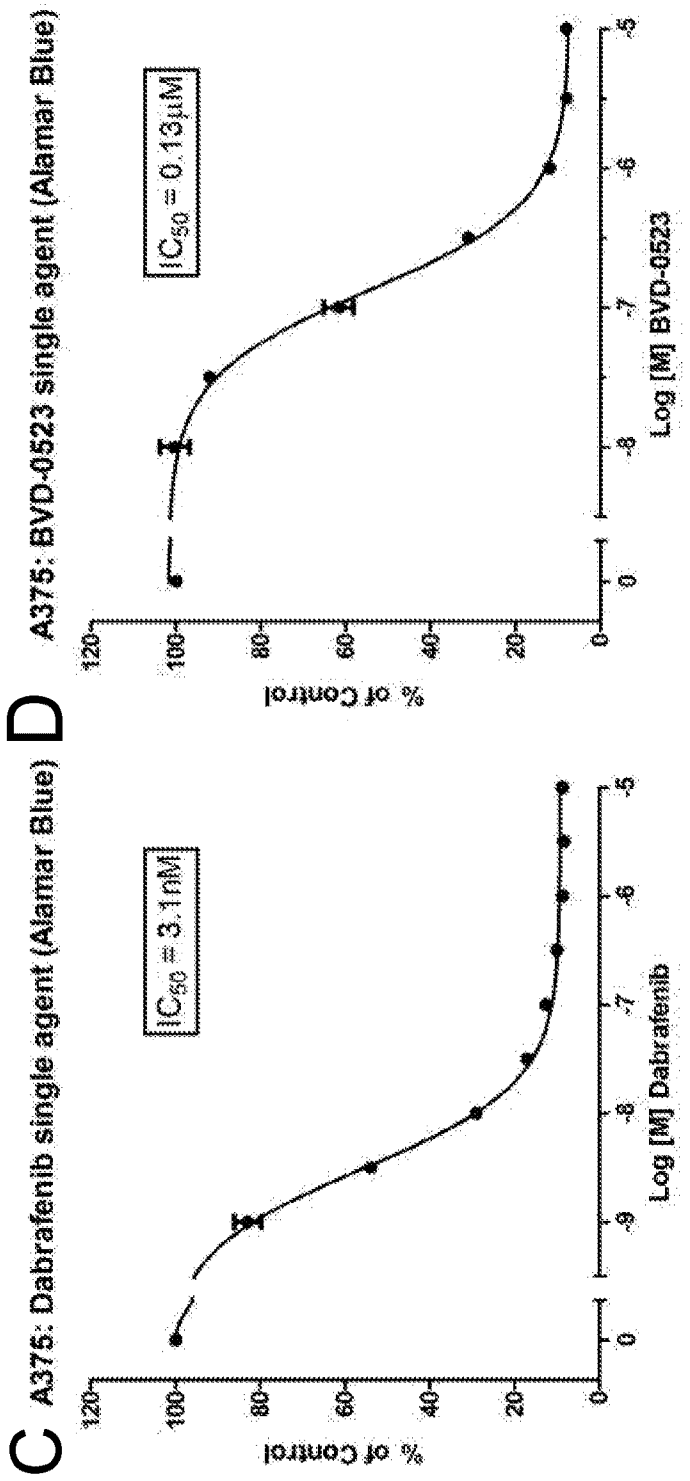


FIG. 41 Con't

A375: Dabrafenib/BVD-523 Combination Assay – Alamar Blue

E

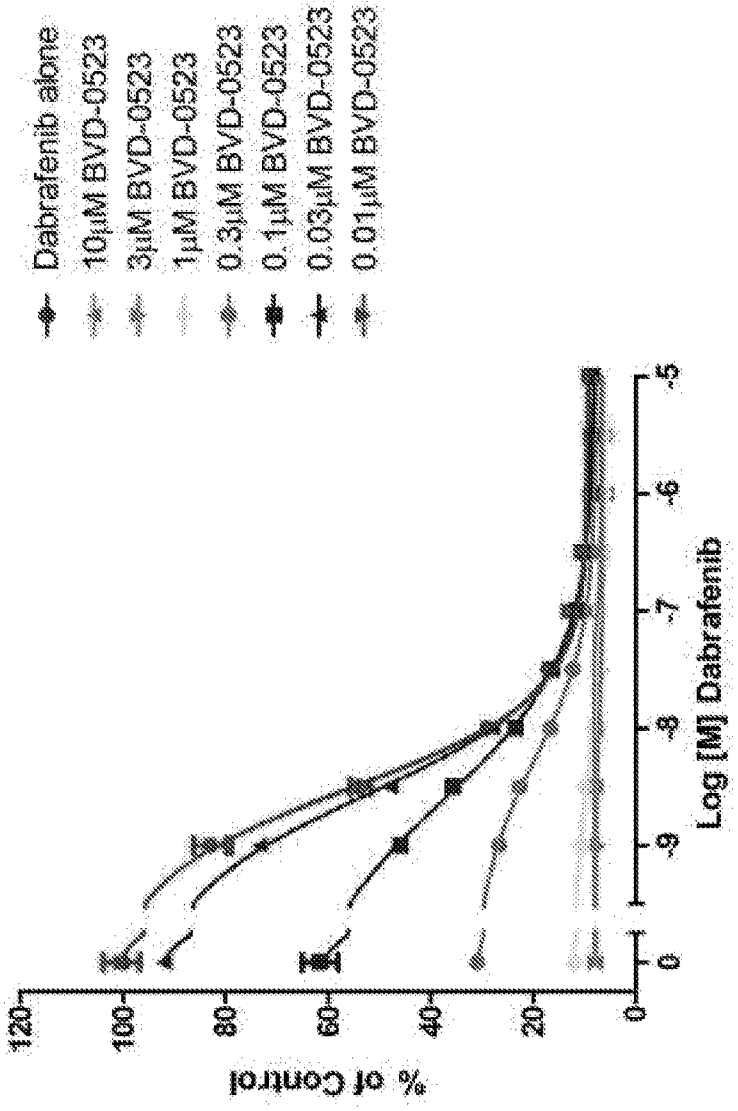


FIG. 42

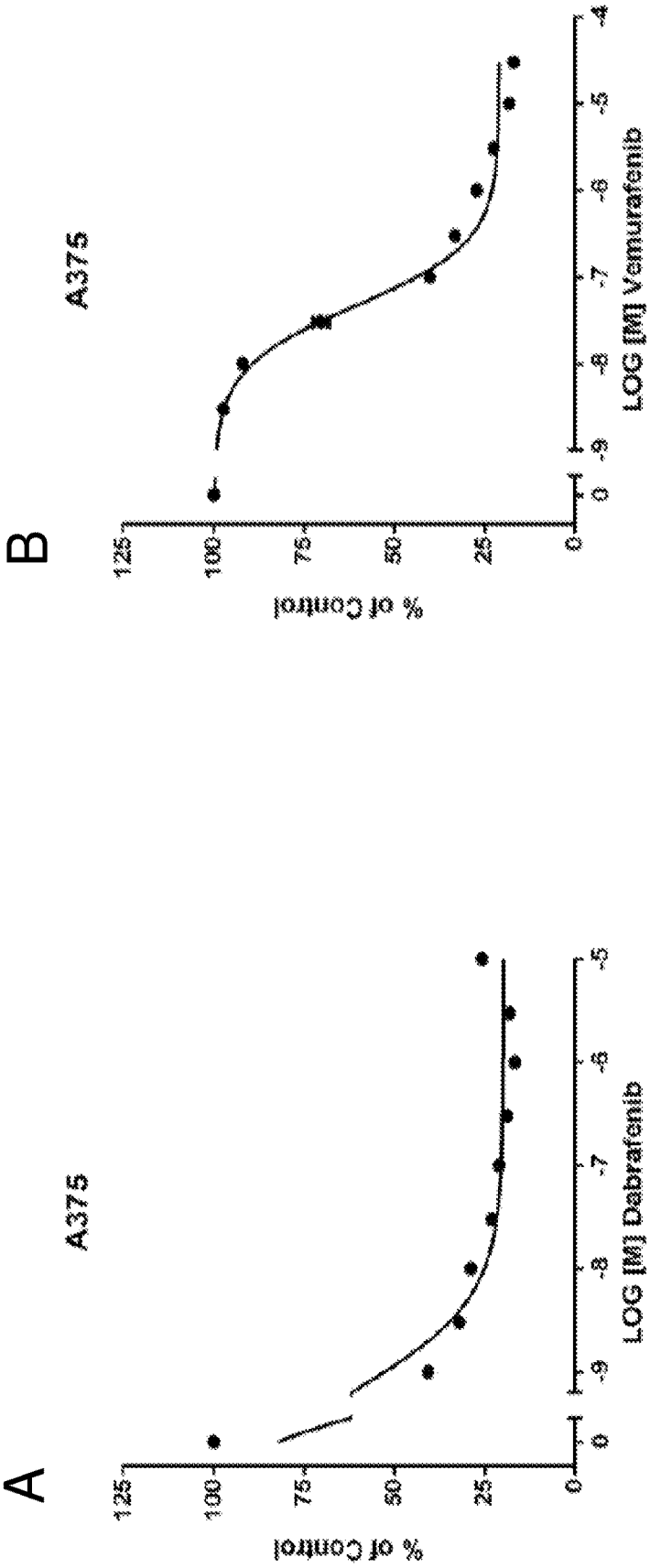

A
A375
% of Control
125
100
75
50
25
0
0
-9
-8
-7
-6
-5
LOG [M] Dabrafenib
B
A375
% of Control
125
100
75
50
25
0
0
-9
-8
-7
-6
-5
-4
LOG [M] Vemurafenib

FIG. 42, Con't

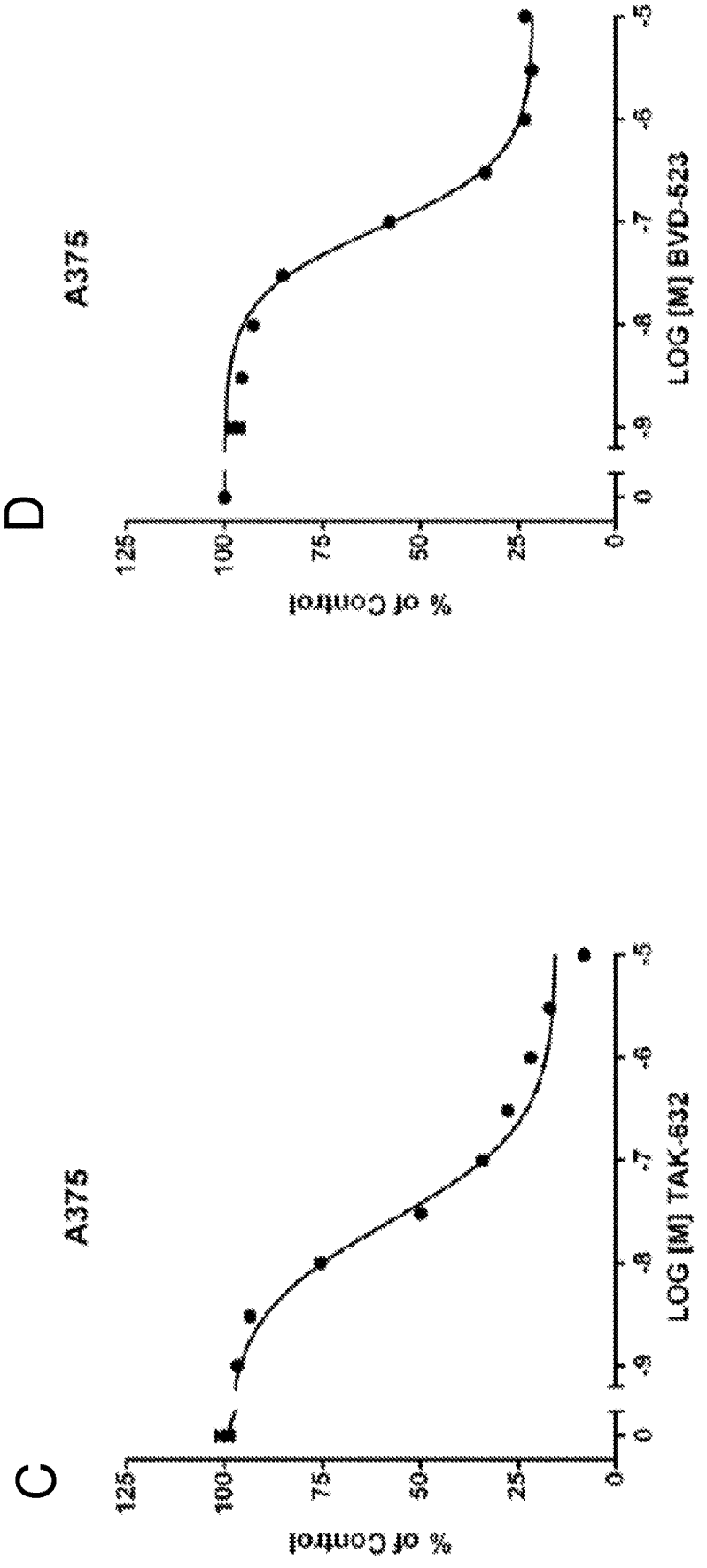
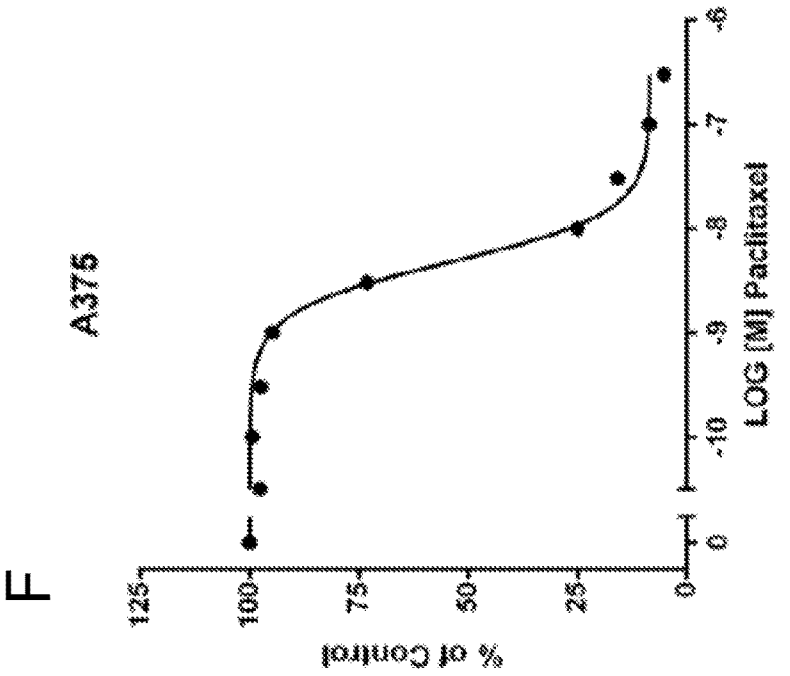

C
A375
% of Control
125
100
75
50
25
0
-9
-8
-7
-6
-5
LOG [M] TAK-632
D
A375
% of Control
125
100
75
50
25
0
-9
-8
-7
-6
-5
LOG [M] BVD-523

FIG. 42, Con't


F
A375
% of Control
125
100
75
50
25
0
0
-10
-9
-8
-7
-6
LOG [M] Paclitaxel

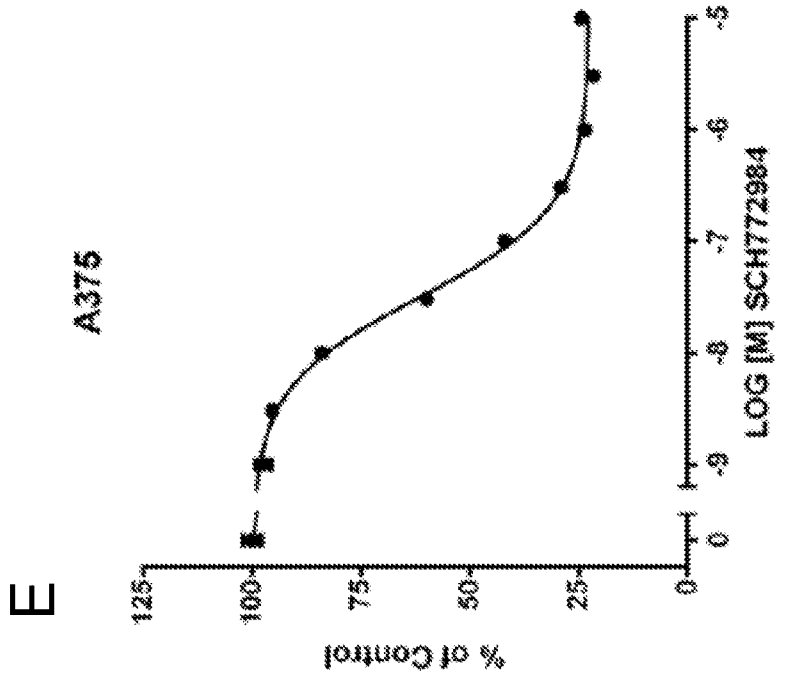

E
A375
% of Control
125
100
75
50
25
0
0
-9
-8
-7
-6
-5
LOG [M] SCH772984

FIG. 42, Con't

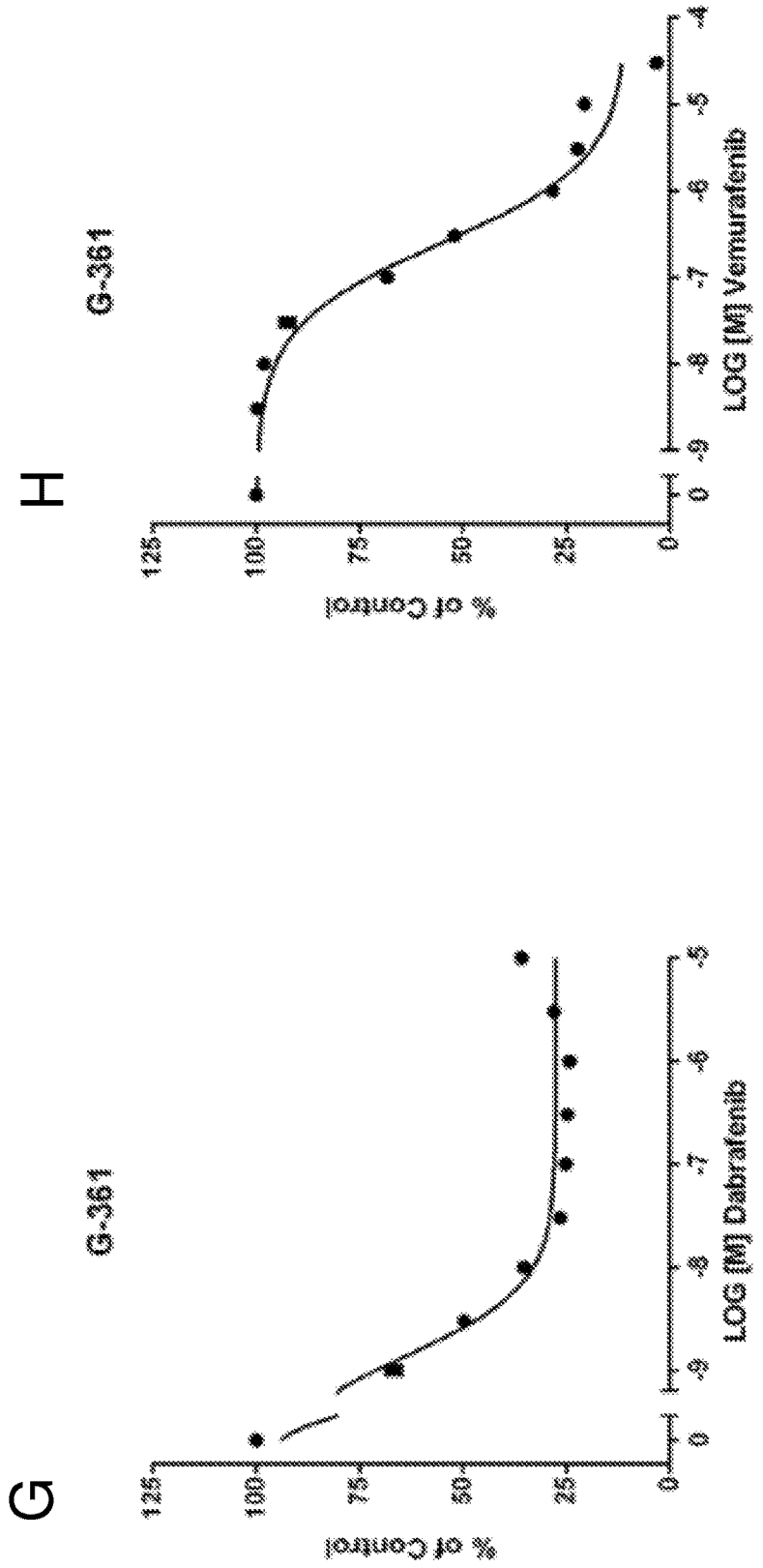
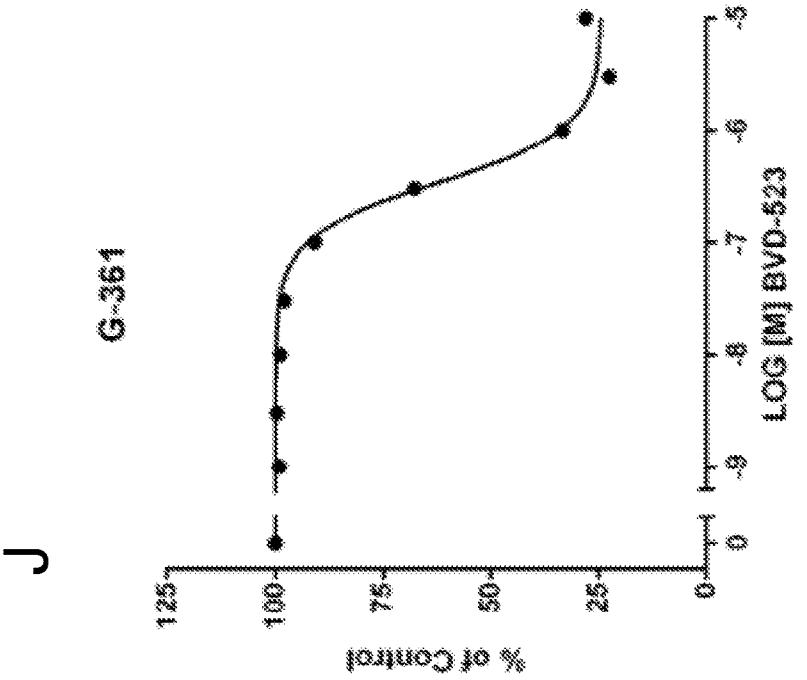

G
G-361
% of Control
125
100
75
50
25
0
-9
-8
-7
-6
-5
LOG [M] Dabrafenib
H
G-361
% of Control
125
100
75
50
25
0
-9
-8
-7
-6
-5
-4
LOG [M] Vemurafenib

FIG. 42, Con't


J
G-361
% of Control
125
100
75
50
25
0
-9
-8
-7
-6
-5
LOG [M] BVD-523

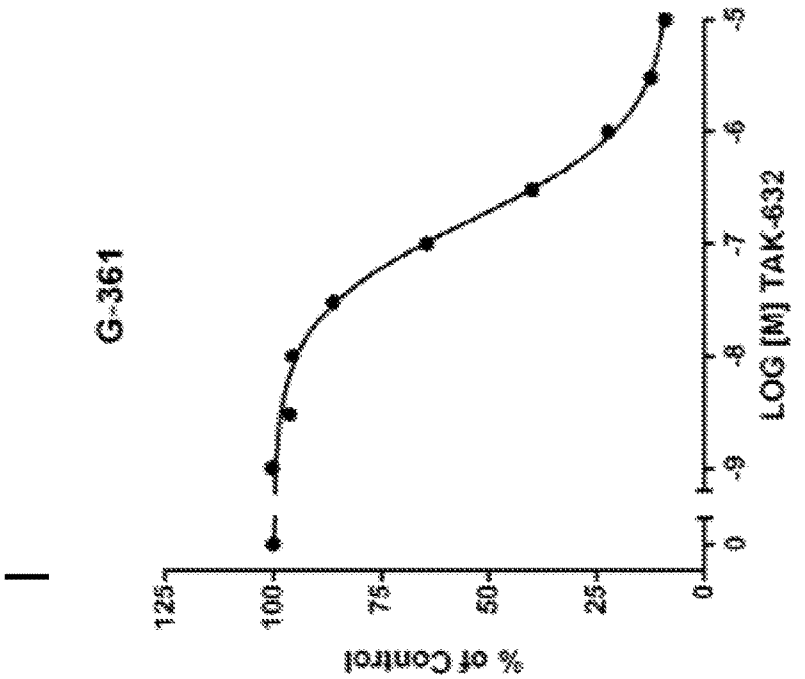

I
G-361
% of Control
125
100
75
50
25
0
-9
-8
-7
-6
-5
LOG [M] TAK-632

FIG. 42, Con't

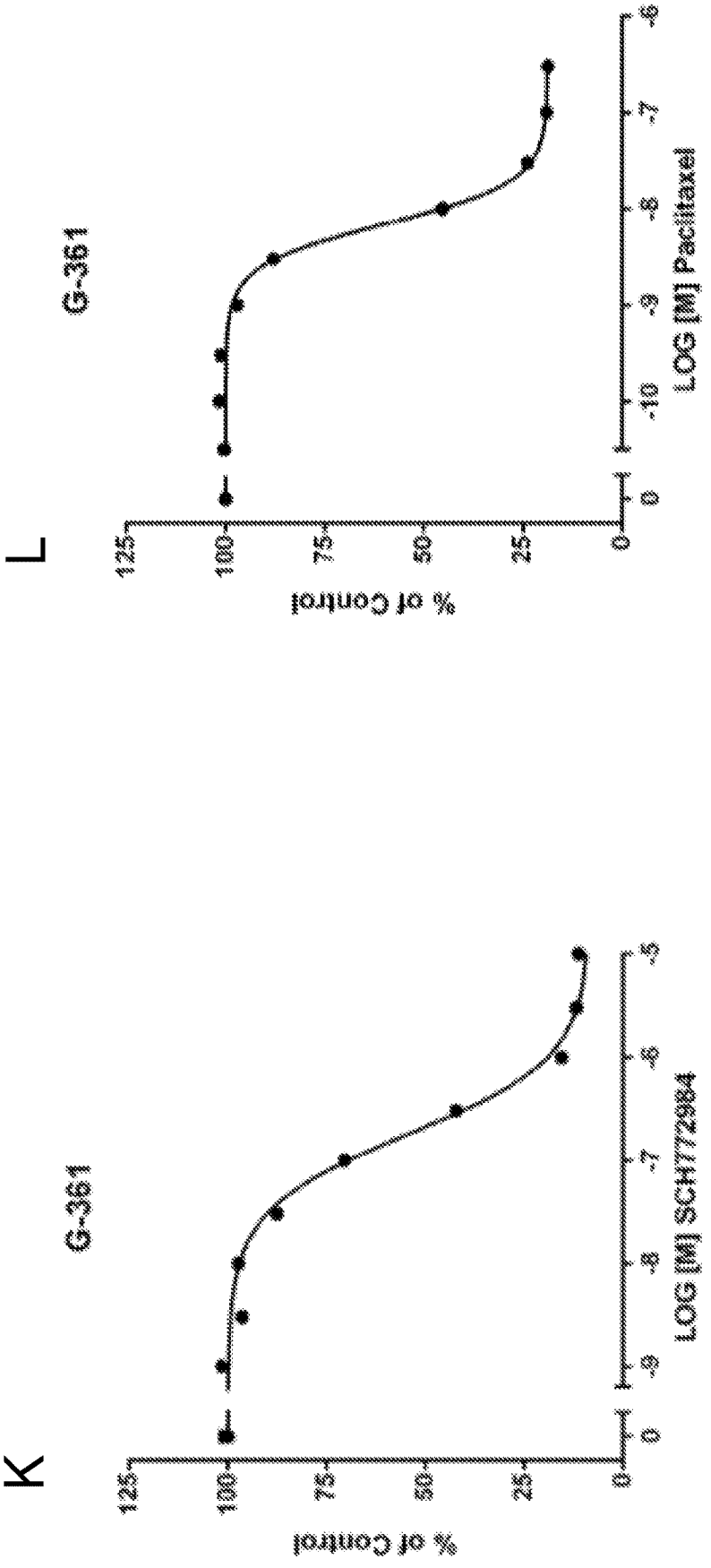

K
G-361
% of Control
125
100
75
50
25
0
0
-9
-8
-7
-6
-5
LOG [M] SCH772984
L
G-361
% of Control
125
100
75
50
25
0
0
-10
-9
-8
-7
-6
LOG [M] Paclitaxel

FIG. 43

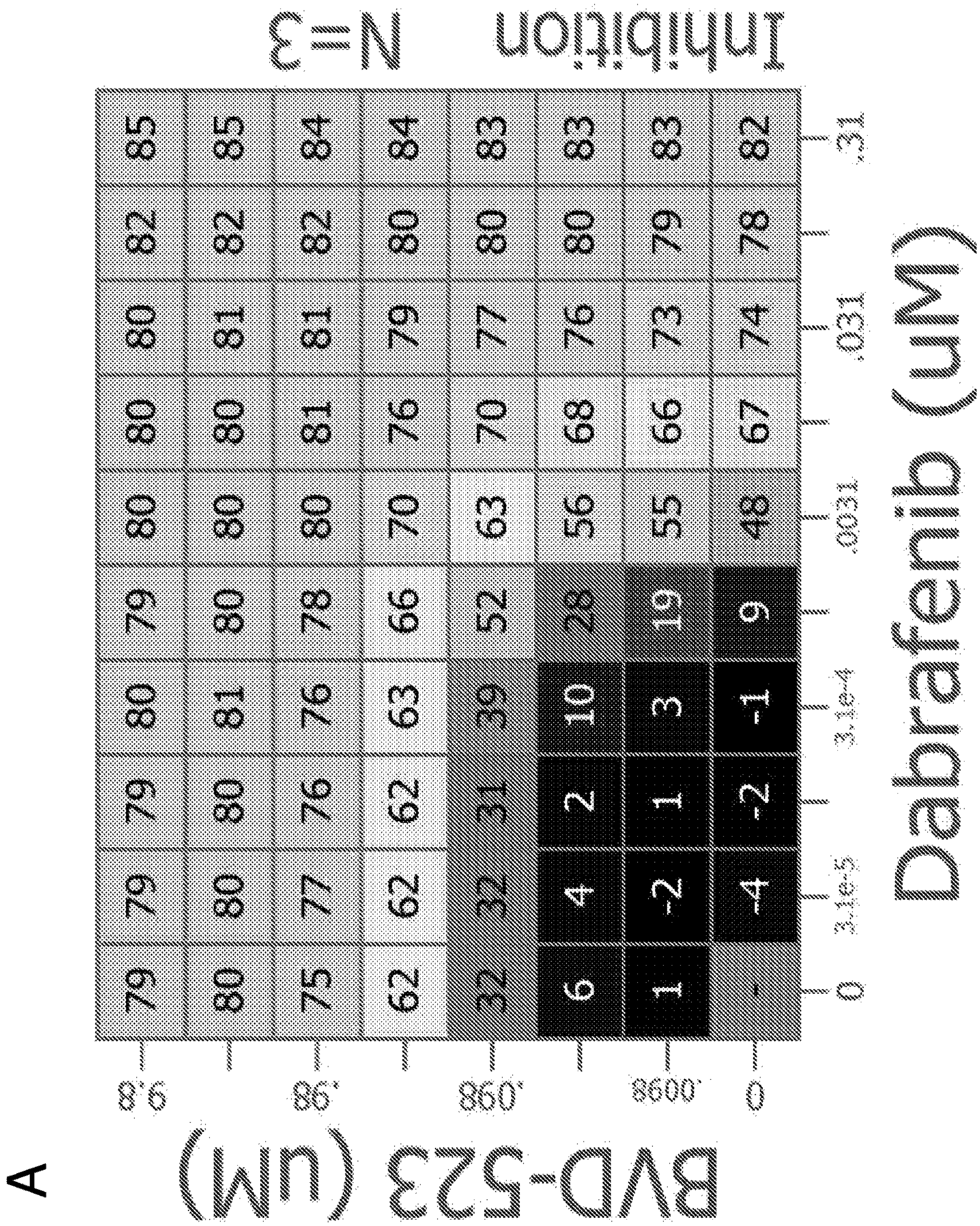

A
BVD-523 (uM)
Dabrafenib (uM)
N=3
Inhibition
9.8
.98
.098
.0098
0
0
3.1e-5
3.1e-4
.0031
.031
.31

FIG. 43, Con't

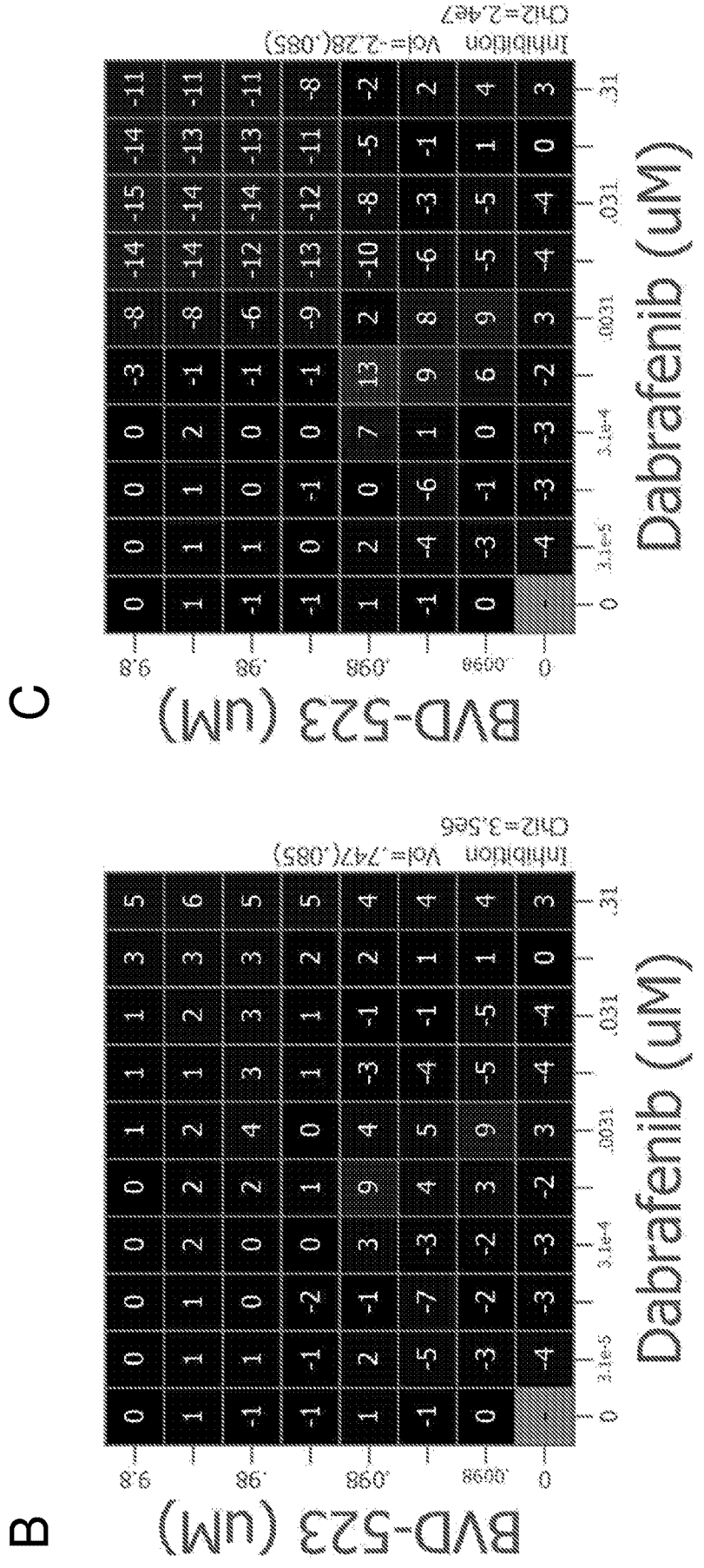

C
BVD-523 (uM)
9.8
.98
.098
.0098
0
Dabrafenib (uM)
0
3.1e-5
.0031
3.1e-4
.031
.31
Inhibition Vol=-2.28(.085)
CI12=2.4e7
B
BVD-523 (uM)
9.8
.98
.098
.0098
0
Dabrafenib (uM)
0
3.1e-5
.0031
3.1e-4
.031
.31
Inhibition Vol=.747(.085)
CI12=3.5e6

FIG. 43, Con't

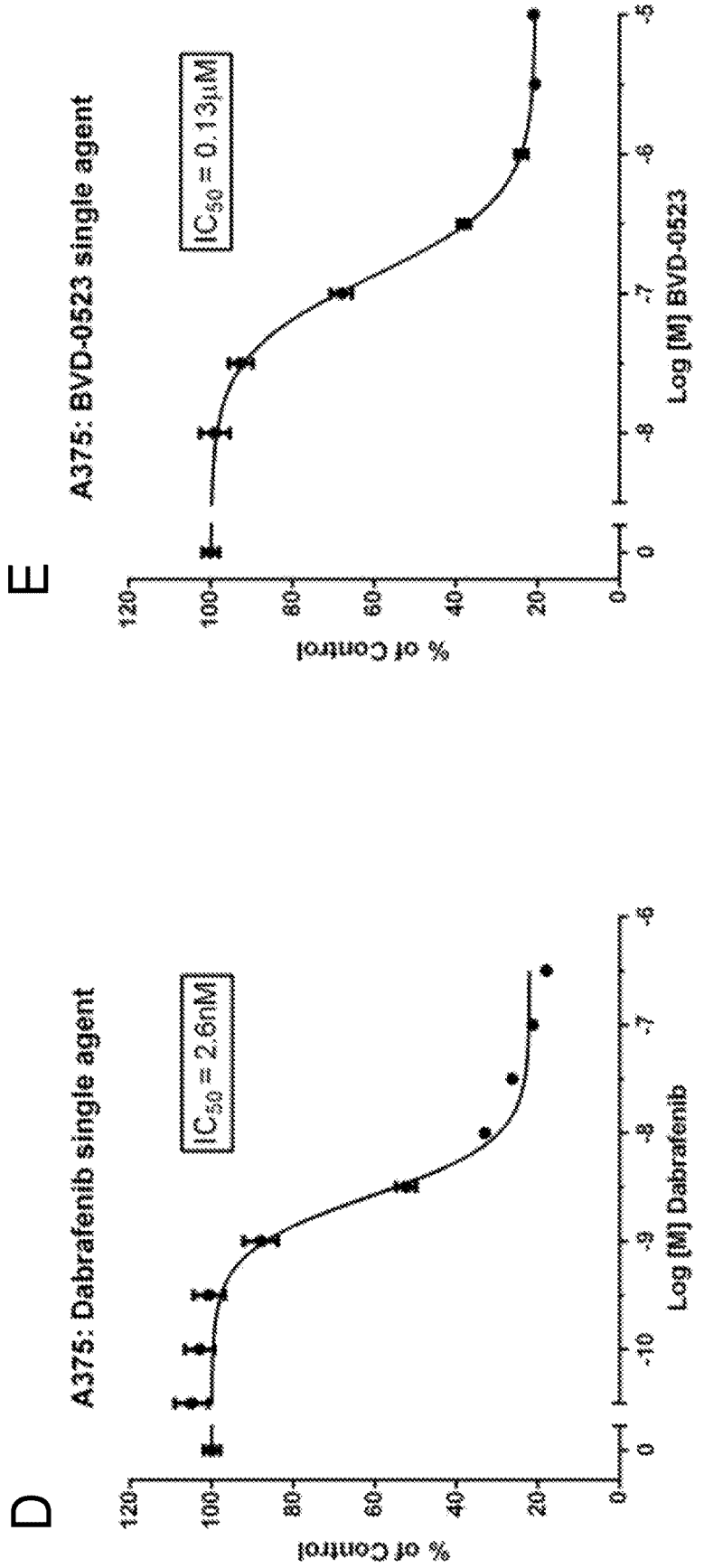

D
A375: Dabrafenib single agent
IC50 = 2.6nM
% of Control
Log [M] Dabrafenib
E
A375: BVD-0523 single agent
IC50 = 0.13μM
% of Control
Log [M] BVD-0523

FIG. 44

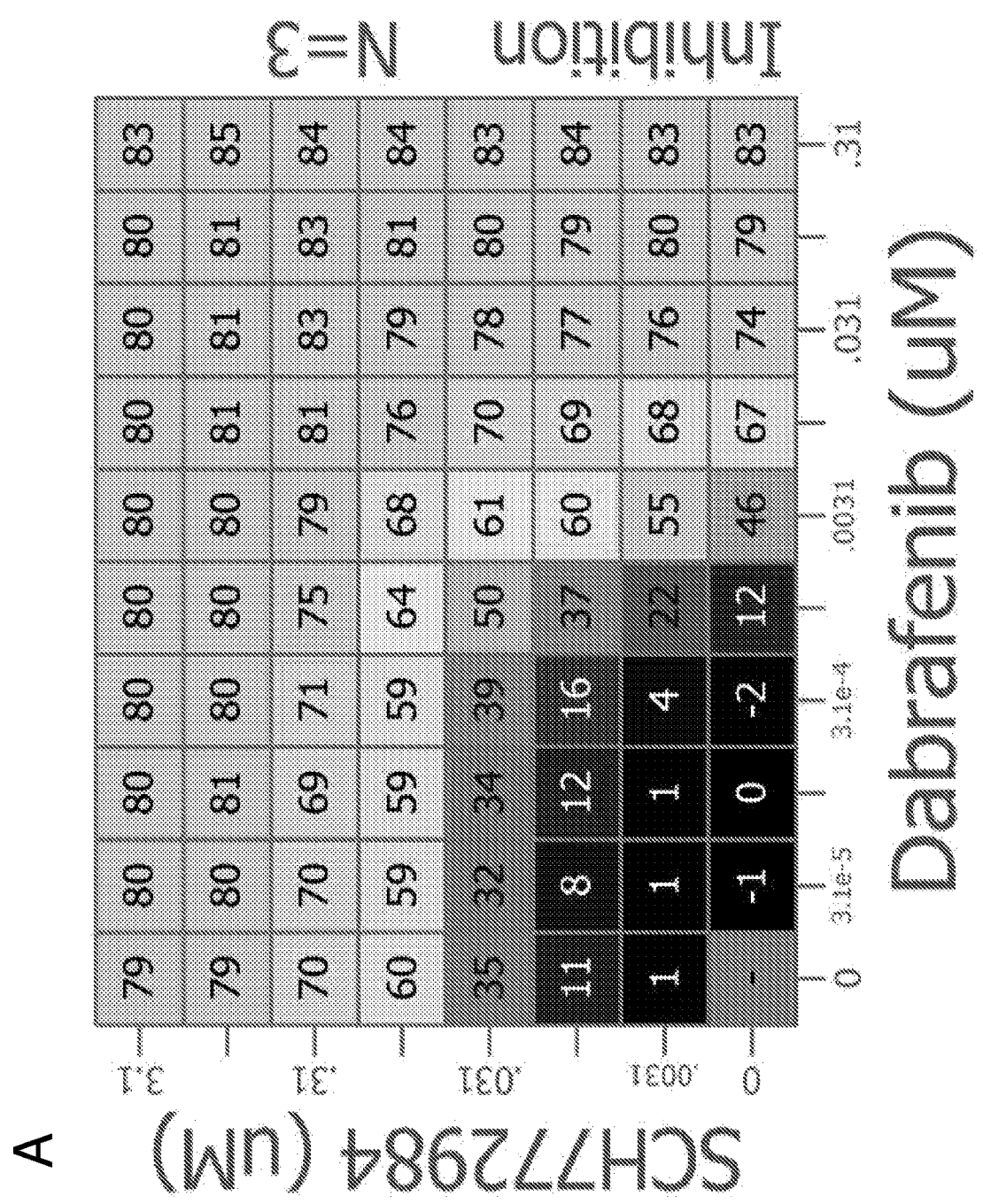

A
SCH772984 (uM)
3.1
.31
.031
.0031
0
Dabrafenib (uM)
0
3.1e-5
.00031
3.1e-4
.0031
.031
.31
Inhibition N=3
79 80 80 80 80 80 80 80 80 83
79 80 80 80 80 81 81 81 81 85
70 70 69 71 75 79 81 83 83 84
60 59 59 59 64 68 76 79 81 84
35 32 34 39 50 61 70 78 80 83
11 8 12 16 37 60 69 77 79 84
1 1 1 4 22 55 68 76 80 83
- -1 0 -2 12 46 67 74 79 83

FIG. 44, Con't

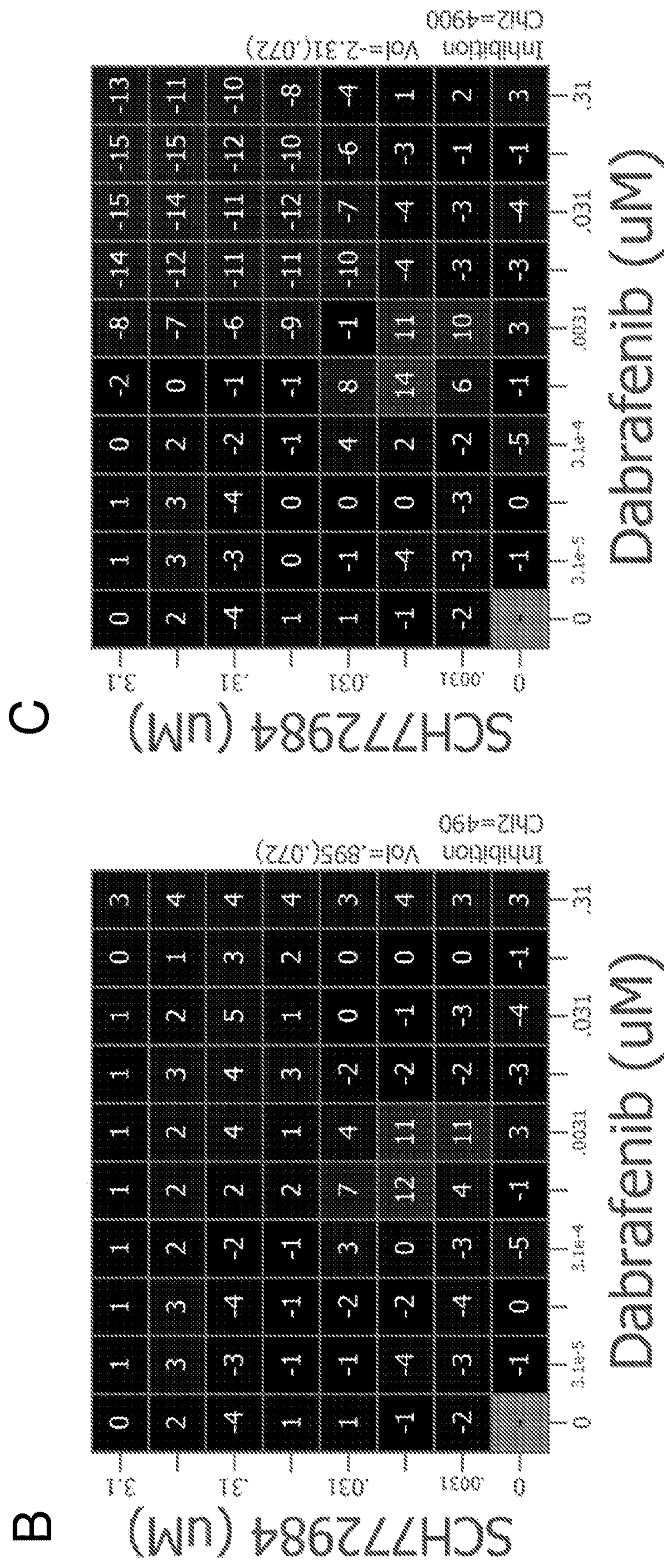

B
SCH772984 (uM)
Dabrafenib (uM)
Inhibition Vol=.895(.072)
Chi2=490
C
SCH772984 (uM)
Dabrafenib (uM)
Inhibition Vol=-2.31(.072)
Chi2=4900

FIG. 44, Con't

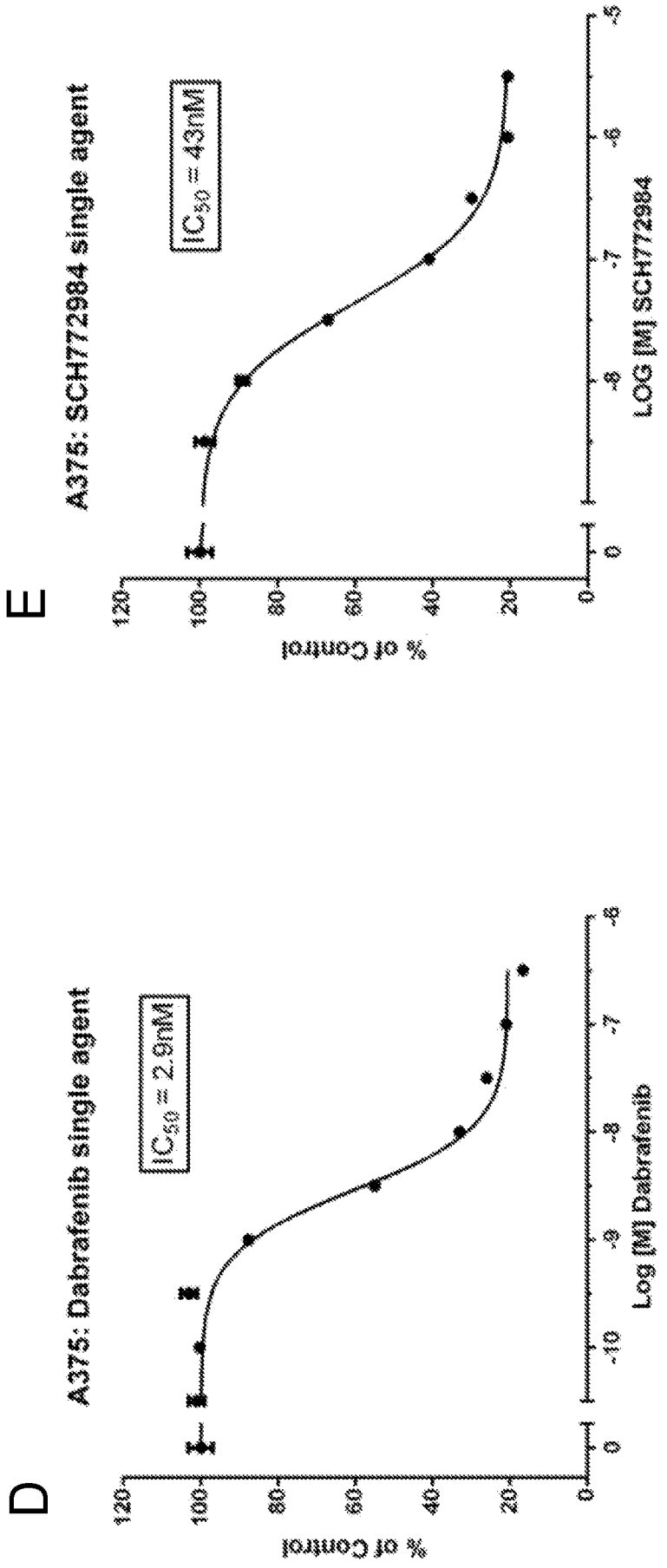

D
A375: Dabrafenib single agent
IC50 = 2.9nM
% of Control
Log [M] Dabrafenib
E
A375: SCH772984 single agent
IC50 = 43nM
% of Control
LOG [M] SCH772984

FIG. 45

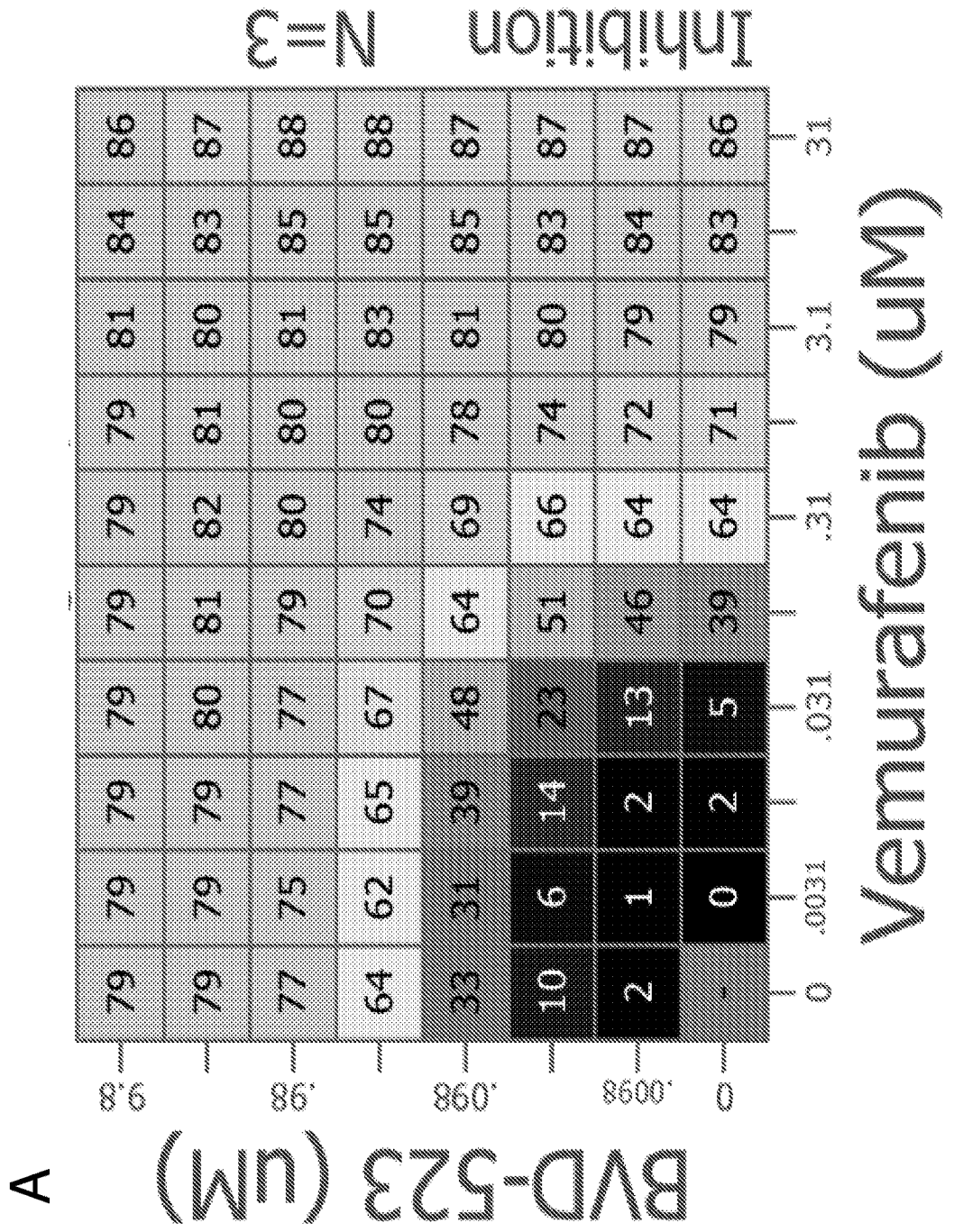
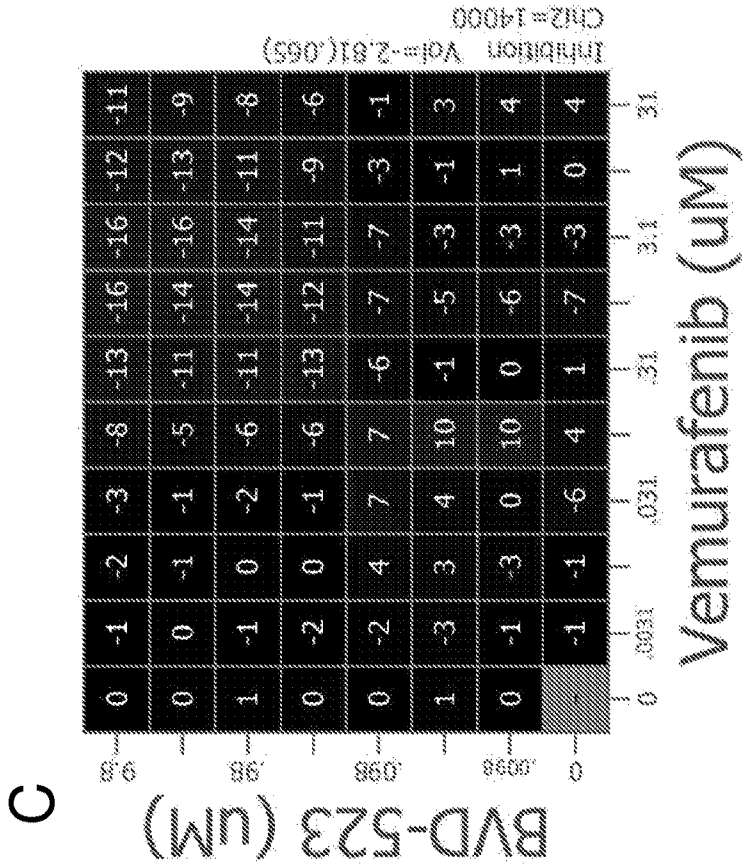

A
BVD-523 (uM)
9.8
3.8
.098
.038
0
Vemurafenib (uM)
0
.0031
.031
.31
3.1
31
Inhibition N=3
79 79 79 79 79 79 79 79 79 79
79 79 79 79 79 80 81 82 81 84
77 75 77 77 77 79 80 80 81 83
64 62 65 67 70 74 74 80 83 85
33 31 39 48 64 69 69 78 81 85
10 6 14 23 51 66 74 80 83 87
2 1 2 13 46 64 72 79 84 87
0 0 2 5 39 64 71 79 83 86
88 87 88 88 87 87 87 87 87 86

FIG. 45, Con't


C
BVD-523 (uM)
Vemurafenib (uM)
Inhibition Vol=-2.81(.065)
Chl2=14000

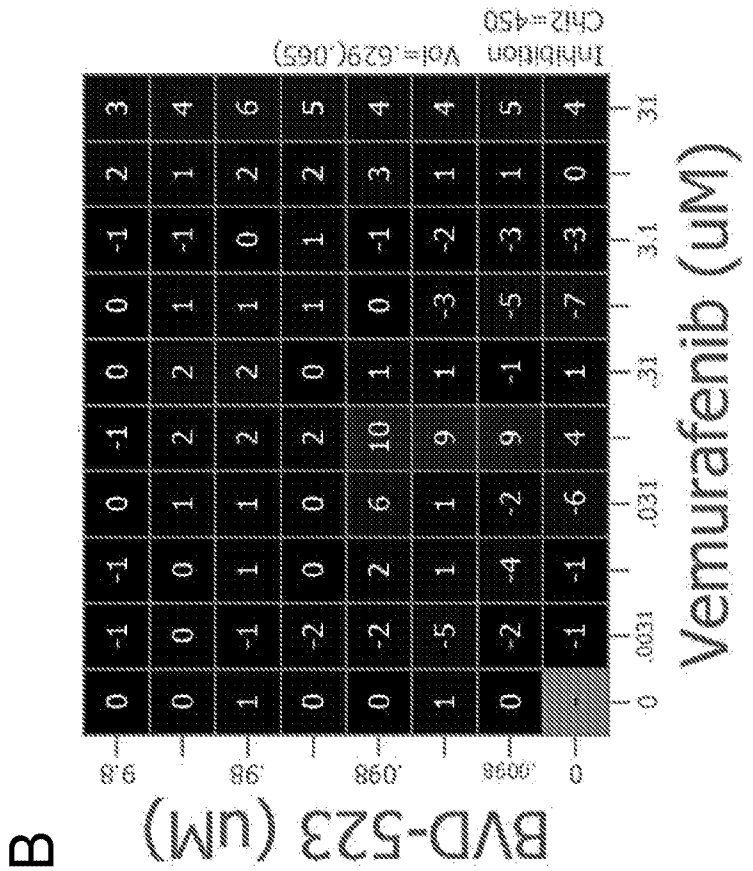

B
BVD-523 (uM)
Vemurafenib (uM)
Inhibition Vol=.629(.065)
Chl2=450

FIG. 45, Con't

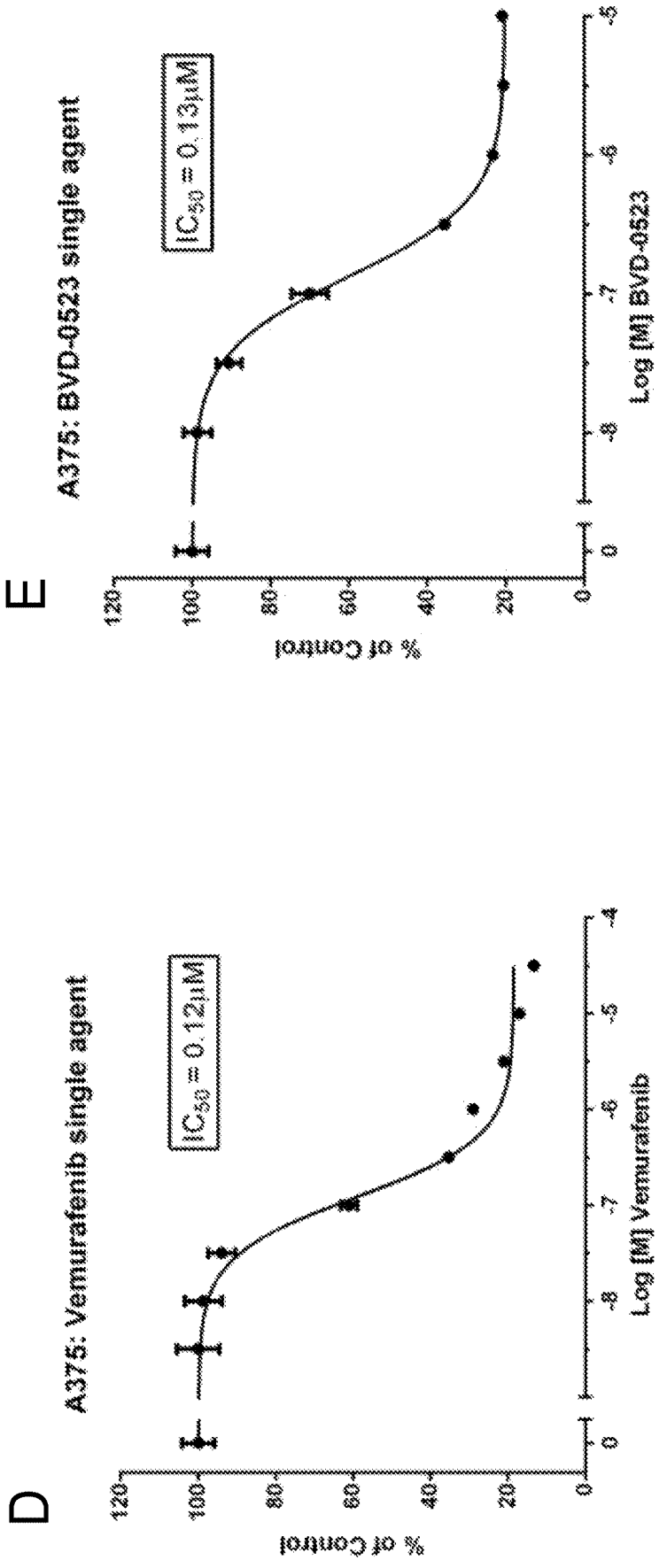

D
A375: Vemurafenib single agent
IC50 = 0.12μM
% of Control
Log [M] Vemurafenib
E
A375: BVD-0523 single agent
IC50 = 0.13μM
% of Control
Log [M] BVD-0523

FIG. 46

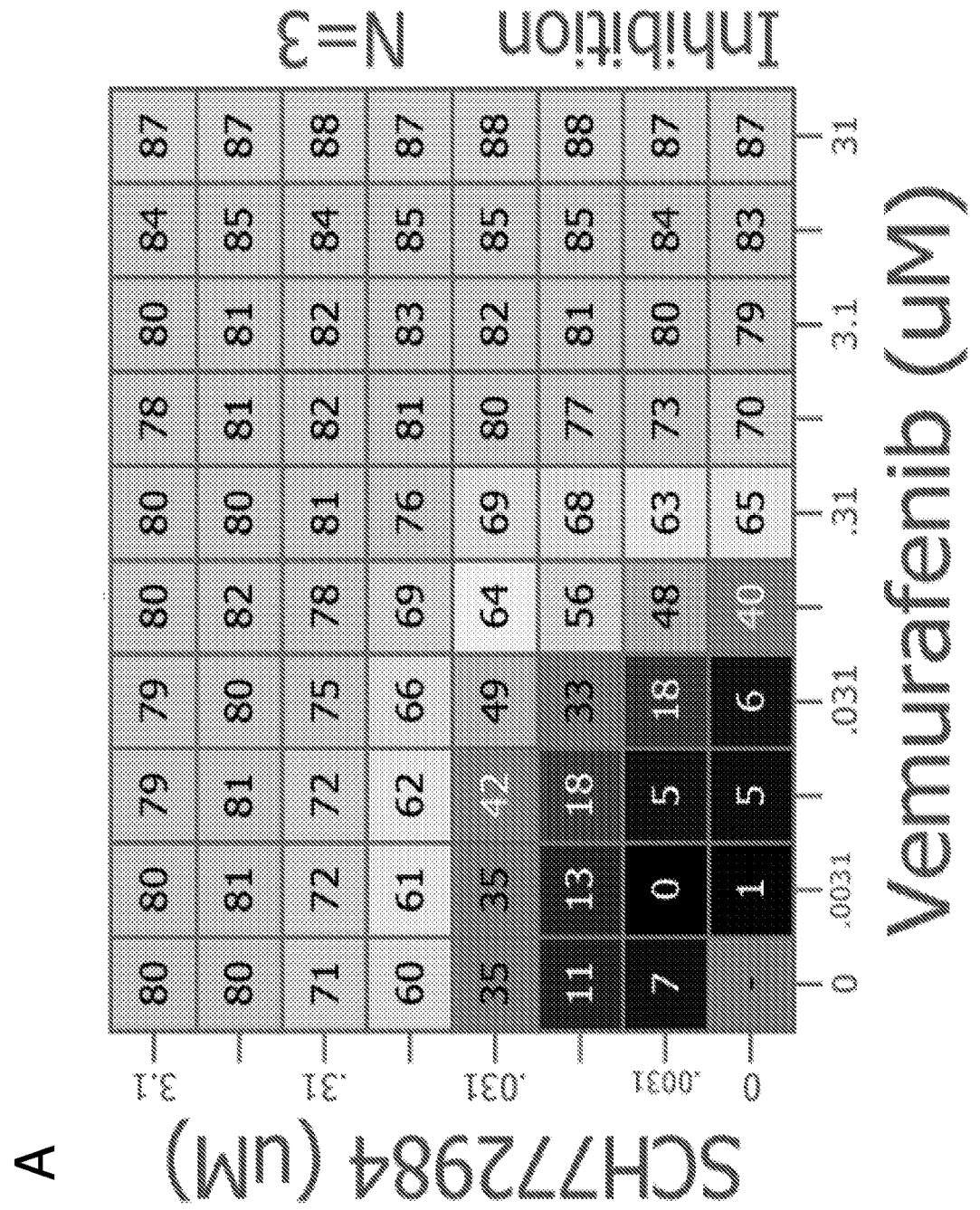
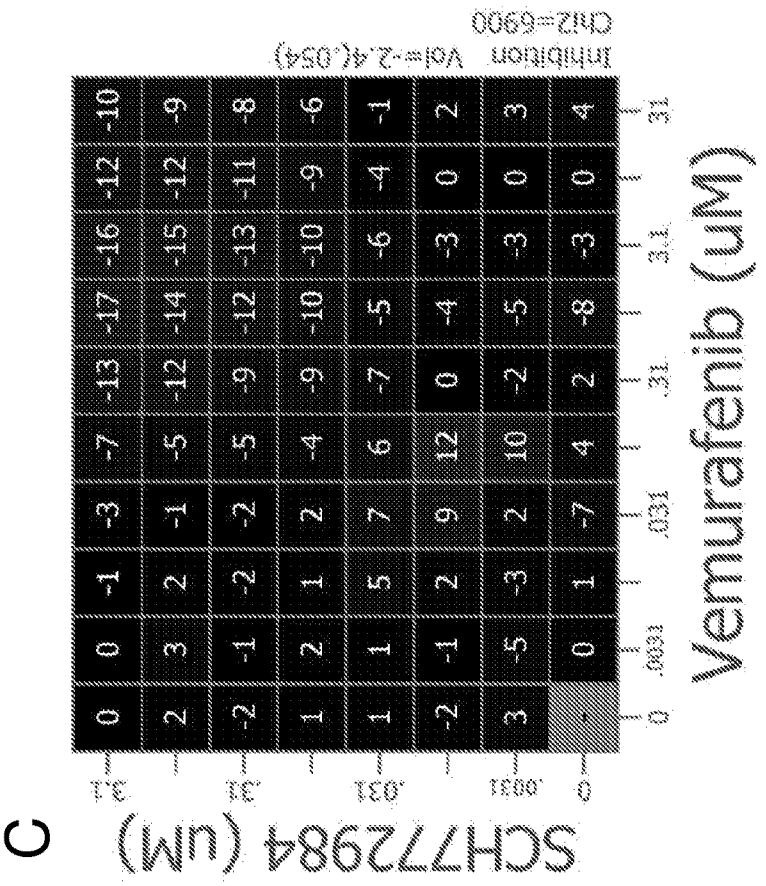

A
SCH772984 (uM)
3.1
.31
.031
.0031
0
Vemurafenib (uM)
0
.0031
.031
.31
3.1
31
Inhibition N=3
80 80 79 79 80 80 80 78 80 84 87
80 81 81 80 82 80 80 81 81 85 87
71 72 72 75 78 81 81 82 82 84 88
60 61 62 66 69 76 81 81 83 85 87
35 35 42 49 64 69 80 80 82 85 88
11 13 18 33 56 68 77 81 81 85 88
7 0 5 18 48 63 73 80 84 87
- 1 5 6 40 65 70 79 83 87

FIG. 46, Con't


C
SCH772984 (uM)
Vemurafenib (uM)
Inhibition Vol=-2.4(.054)
CH2=6900

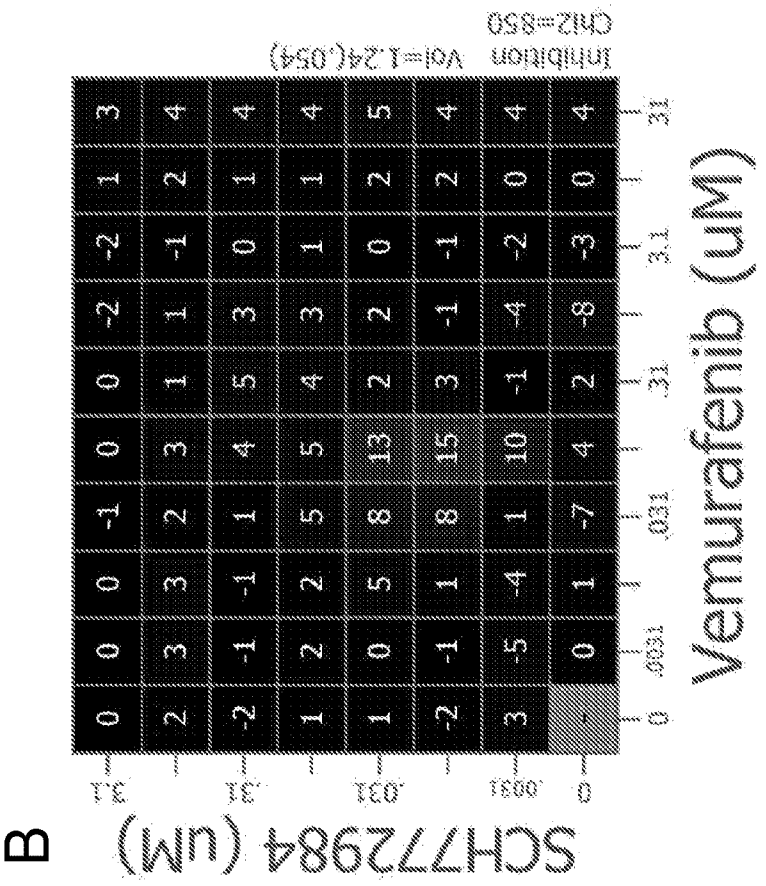

B
SCH772984 (uM)
Vemurafenib (uM)
Inhibition Vol=1.24(.054)
CH2=850

FIG. 46, Con't

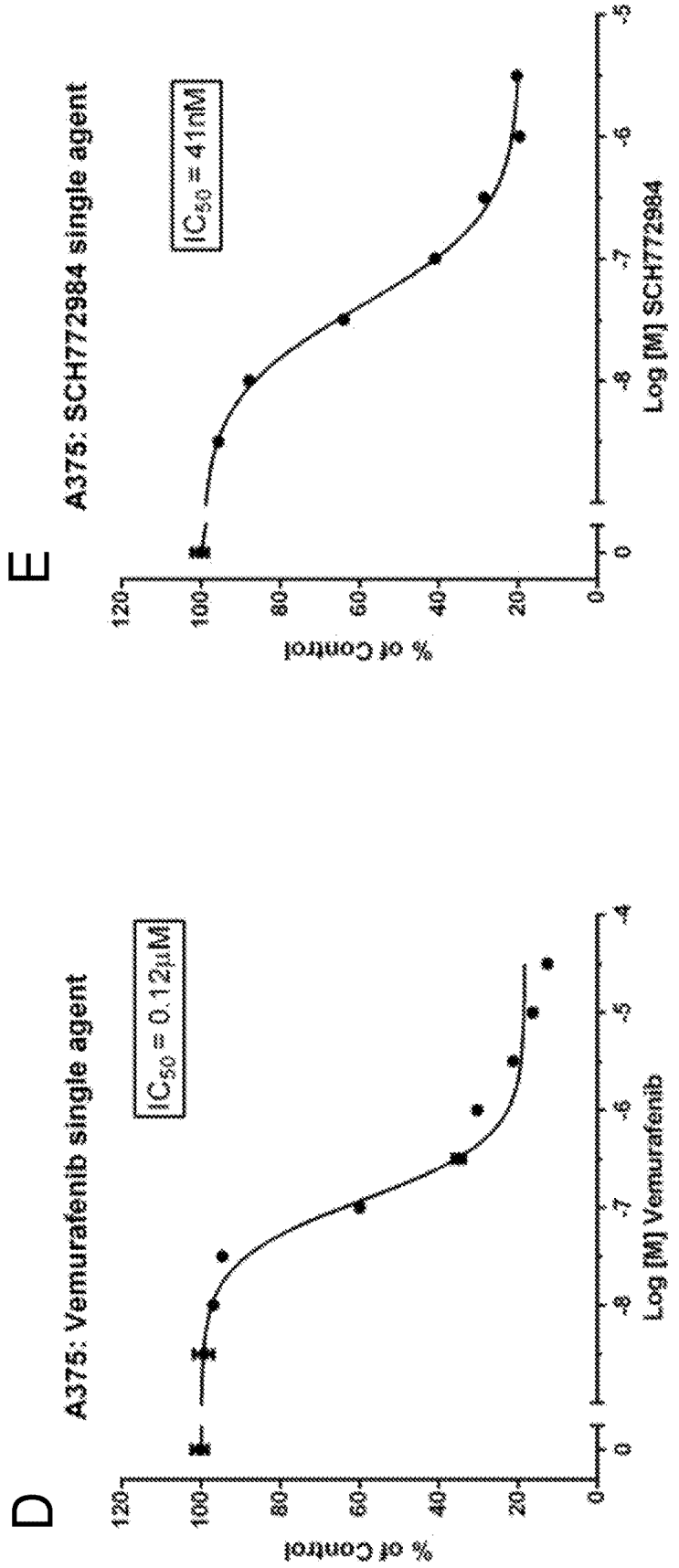

D
A375: Vemurafenib single agent
IC50 = 0.12µM
% of Control
Log [M] Vemurafenib
E
A375: SCH772984 single agent
IC50 = 41nM
% of Control
Log [M] SCH772984

FIG. 47

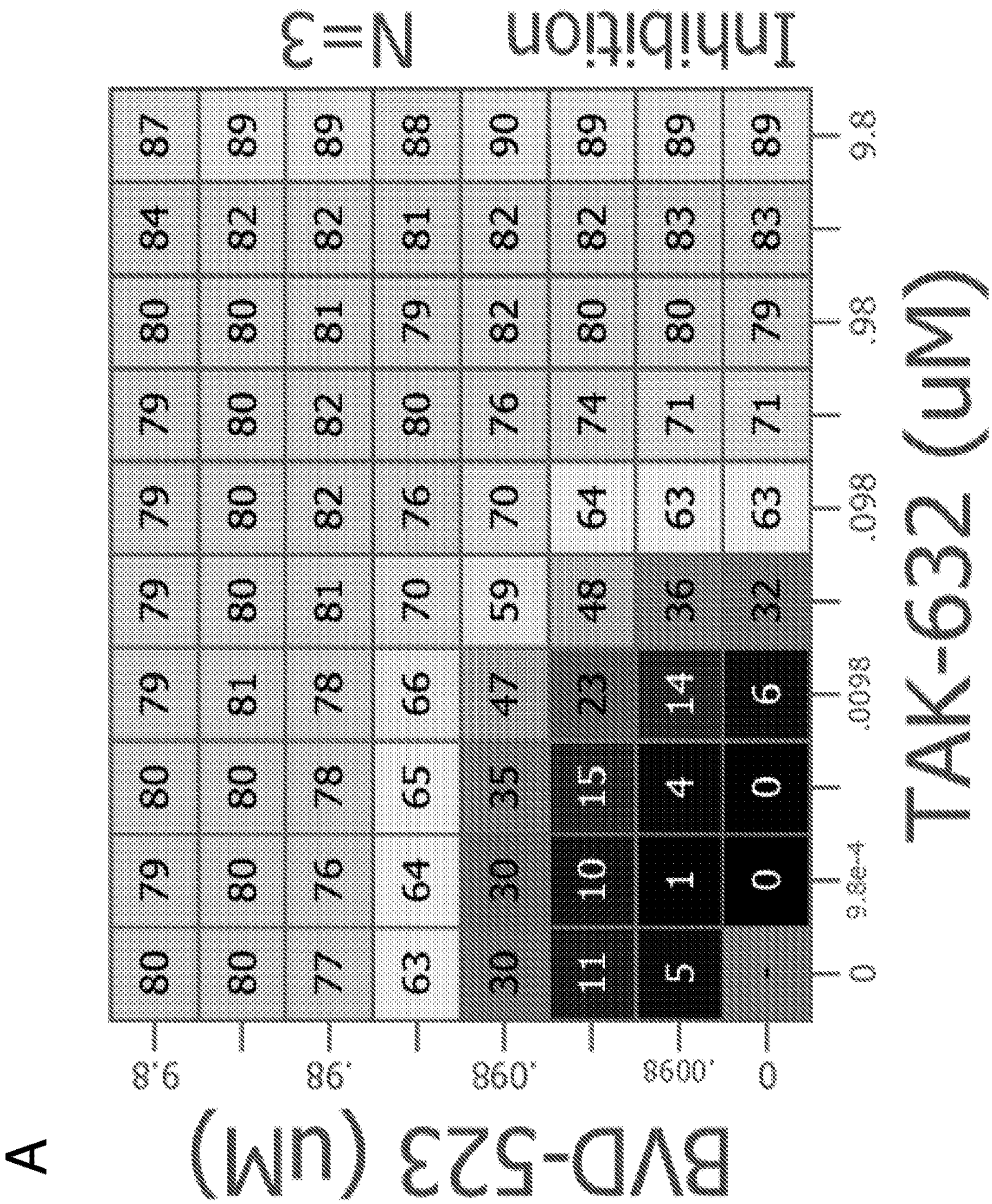
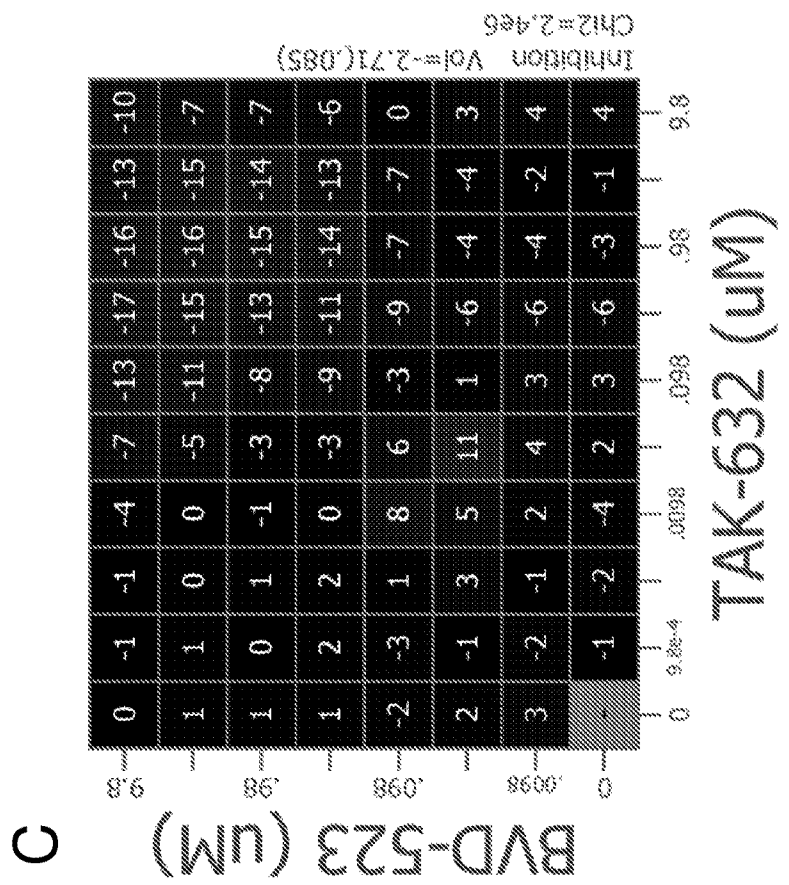


FIG. 47, Con't


C
BVD-523 (uM)
TAK-632 (uM)
Inhibition Vol=-2.71(.085)
Chi2=2.4e6
0
.0098
.098
.98
9.8
9.8e-4

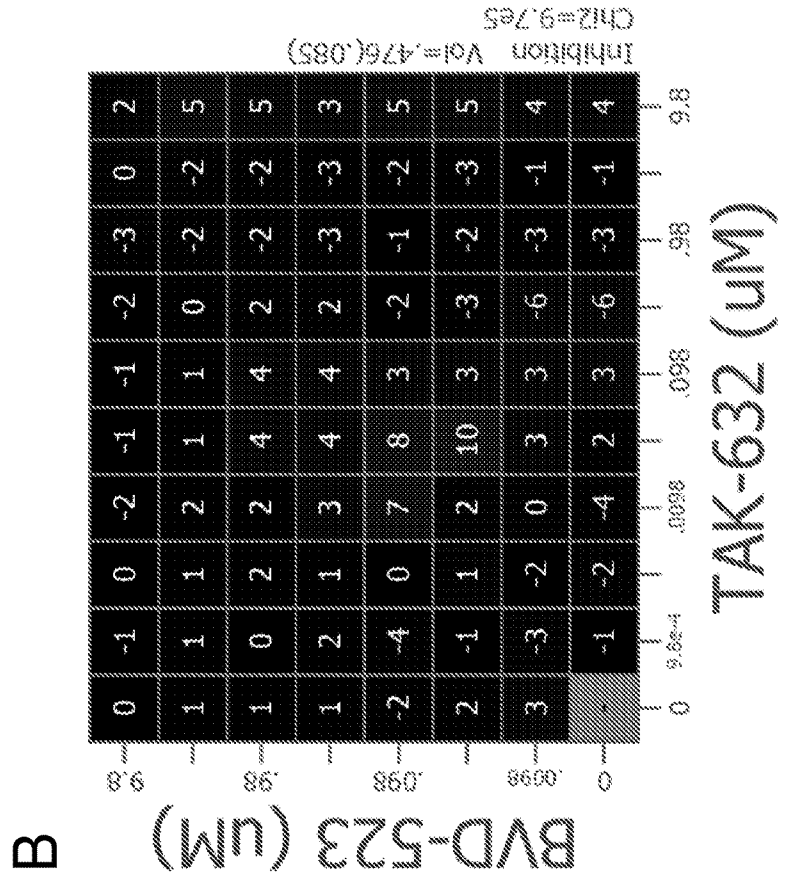
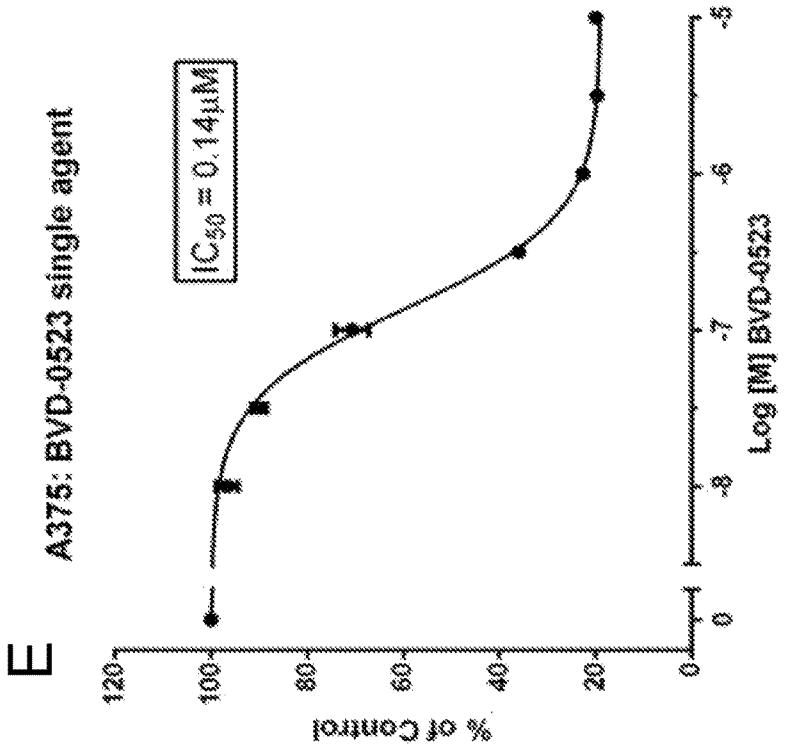

B
BVD-523 (uM)
TAK-632 (uM)
Inhibition Vol=.476(.085)
Chi2=9.7e5
0
.0098
.098
.98
9.8
9.8e-4

FIG. 47, Con't


E
A375: BVD-0523 single agent
IC_{50} = 0.14μM
% of Control
Log [M] BVD-0523

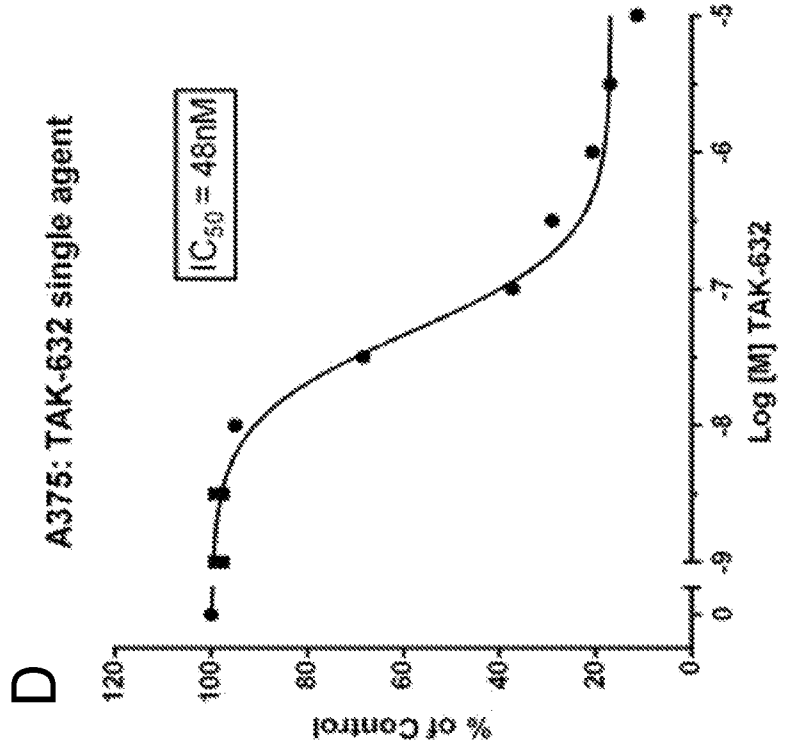

D
A375: TAK-632 single agent
IC_{50} = 48nM
% of Control
Log [M] TAK-632

FIG. 48

A

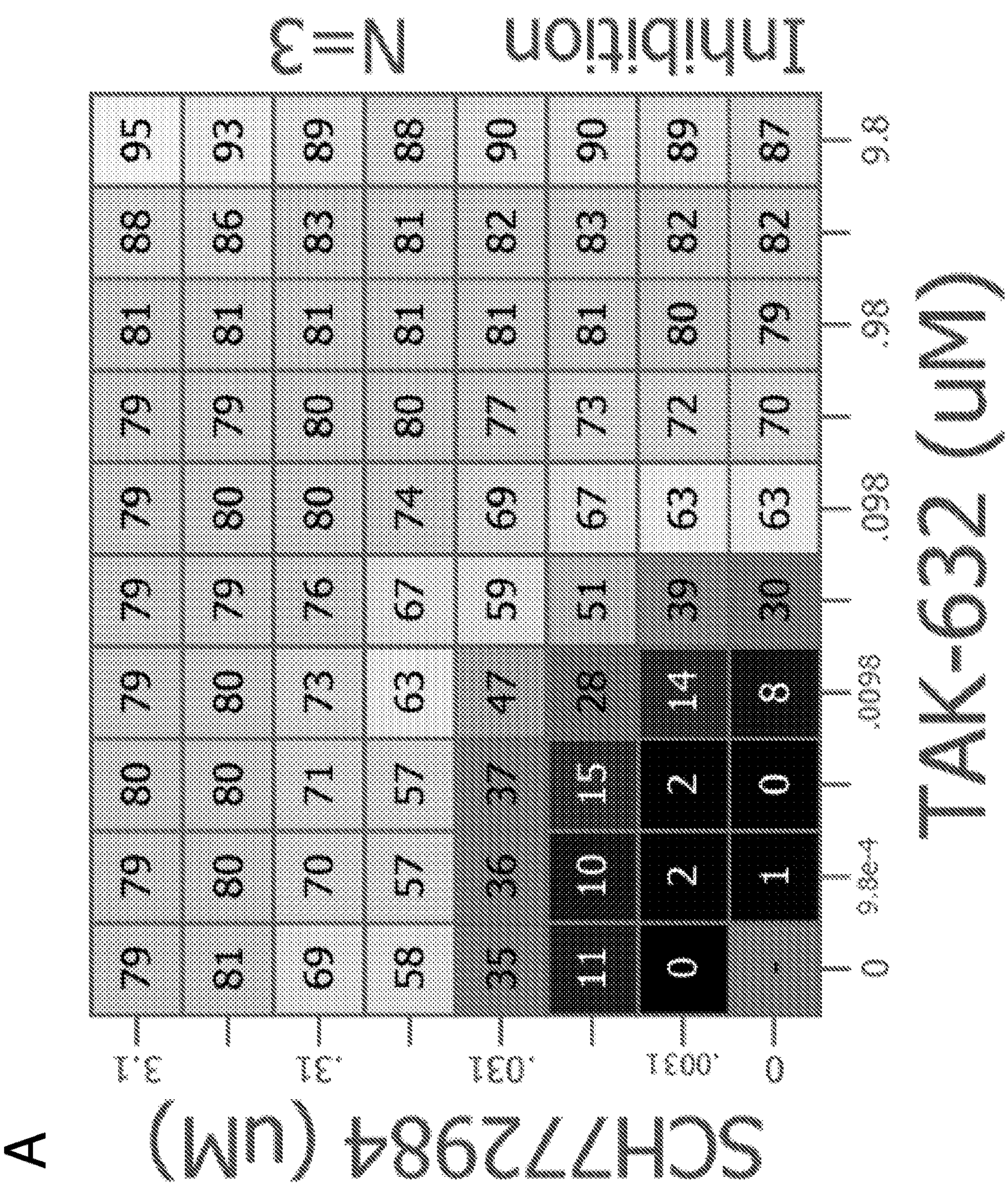
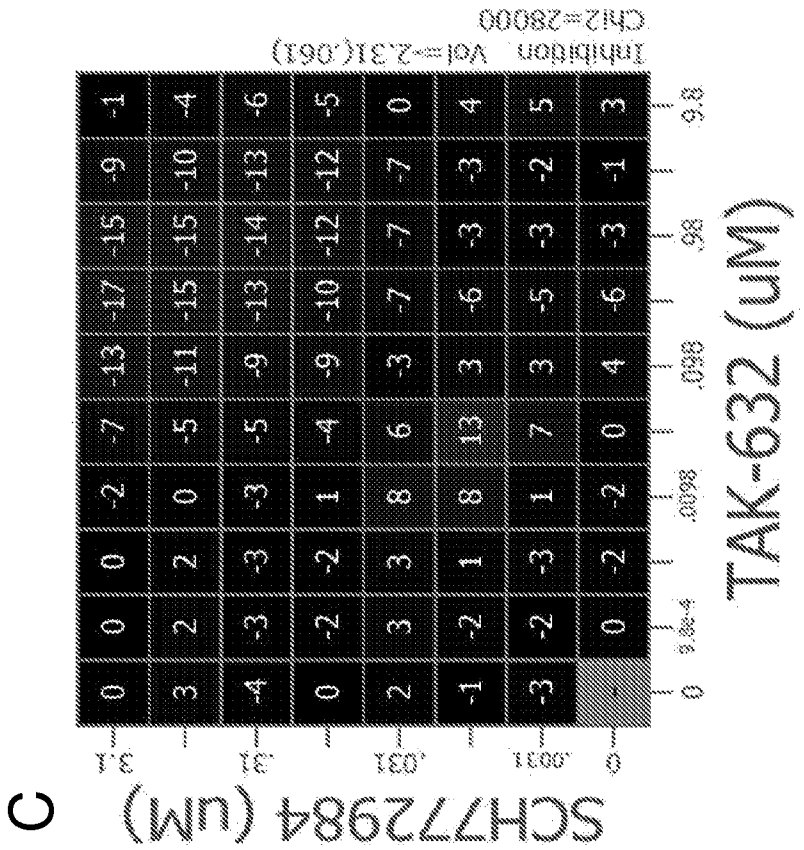

Inhibition
N=3
SCH772984 (uM)
3.1
.31
.031
.0031
0
TAK-632 (uM)
0
9.8e-4
.0098
.098
.98
9.8
79 79 80 79 79 79 79 81 88 95
81 80 80 80 79 80 79 81 86 93
69 70 71 73 76 80 80 81 83 89
58 57 57 63 67 74 80 81 81 88
35 36 37 47 59 69 77 81 82 90
11 10 15 28 51 67 73 81 83 90
0 2 2 14 39 63 72 80 82 89
- 1 0 8 30 63 70 79 82 87

FIG. 48, Con't


C
SCH772984 (uM)
0
.0031
.031
.31
3.1
Inhibition Vol=-2.31(.061)
CH2=28000
TAK-632 (uM)
0
9.8e-4
.0098
.098
.98
9.8
0 3 -4 0 2 -3 -1 -3 -2 0
0 3 -3 -2 2 3 -2 3 -2 0
0 2 -2 -1 2 3 0 -4 -2
0 2 -1 3 9 7 0 -2
-1 1 2 3 12 13 7 0
-1 1 5 4 4 6 3 4
-1 0 2 3 1 -3 -4 -6
-1 -1 -1 -2 -1 -1 -2 -3
4 2 -1 -2 -1 -1 -1 -1
11 9 5 4 6 6 5 3

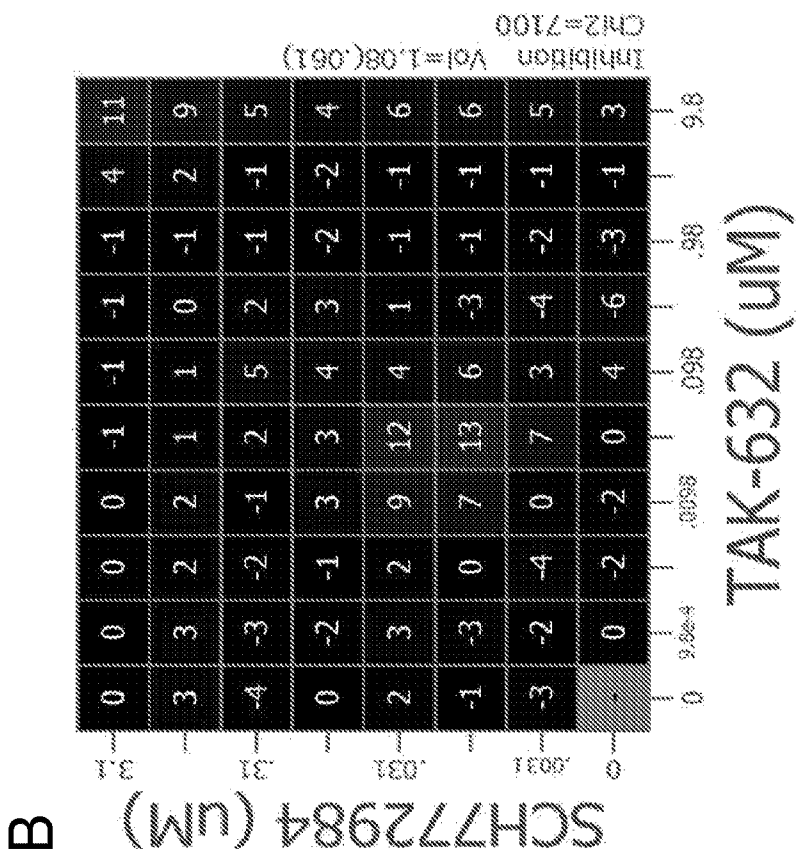

B
SCH772984 (uM)
0
.0031
.031
.31
3.1
Inhibition Vol=-1.08(.061)
CH2=7100
TAK-632 (uM)
0
9.8e-4
.0098
.098
.98
9.8
0 3 -4 0 2 -1 -3 -2 0
0 3 -3 -2 3 -3 2 -2 0
0 2 -2 -1 2 -1 -4 -2
0 2 -1 3 9 7 0 -2
-1 1 2 3 12 13 7 0
-1 1 5 4 4 6 3 4
-1 0 2 3 1 -3 -4 -6
-1 -1 -1 -2 -1 -1 -2 -3
4 2 -1 -2 -1 -1 -1 -1
11 9 5 4 6 6 5 3

FIG. 48, Con't

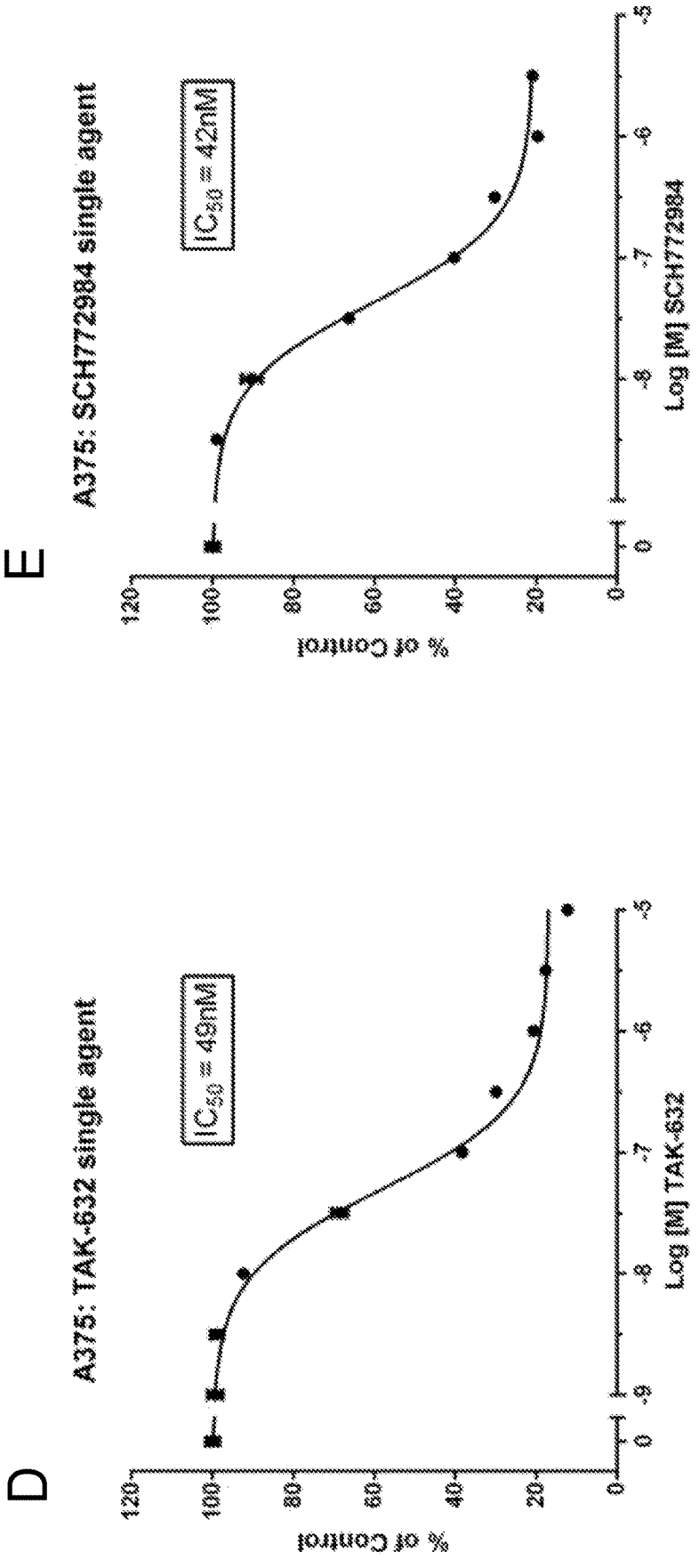

D
A375: TAK-632 single agent
IC50 = 49nM
% of Control
Log [M] TAK-632
E
A375: SCH772984 single agent
IC50 = 42nM
% of Control
Log [M] SCH772984

FIG. 49

A

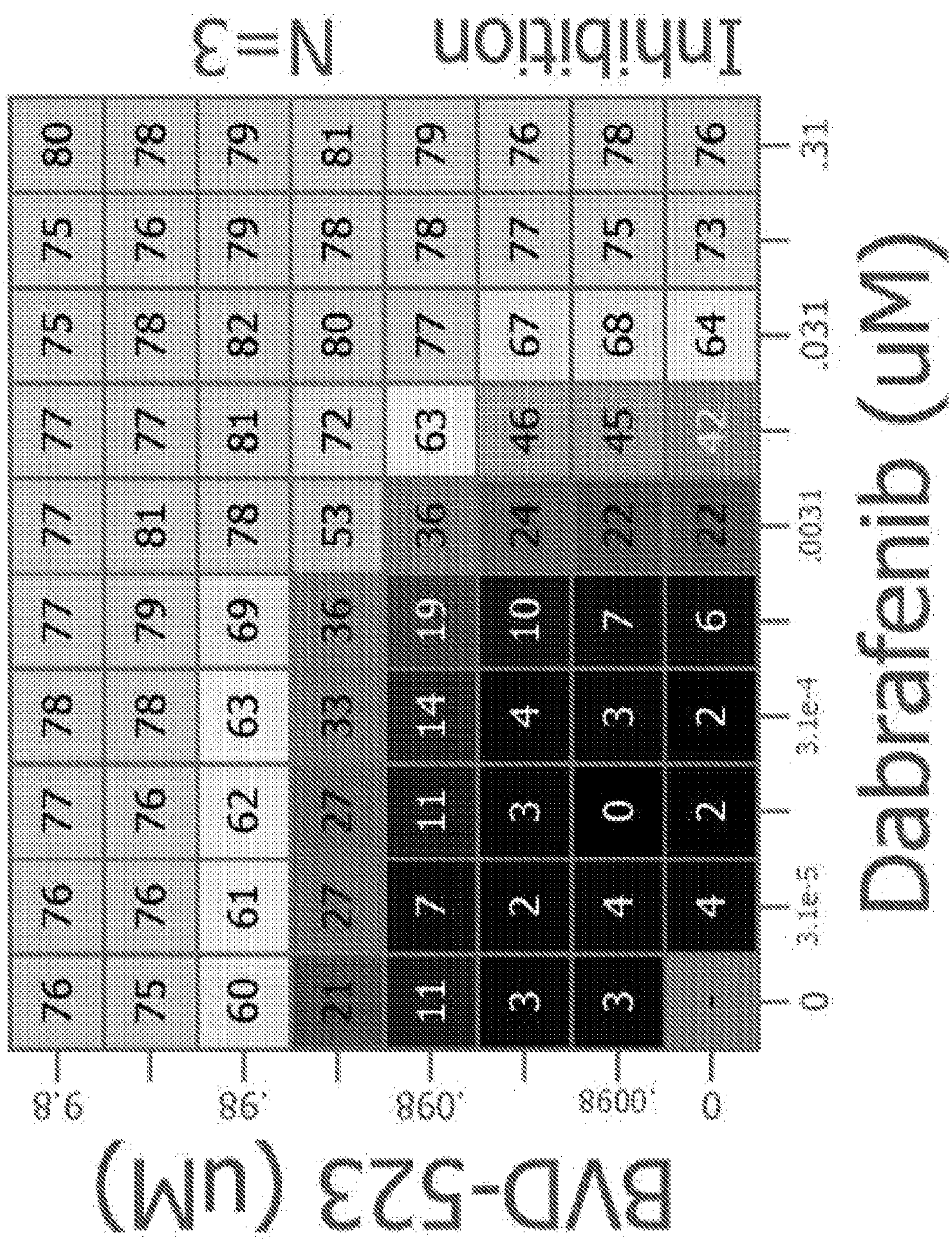
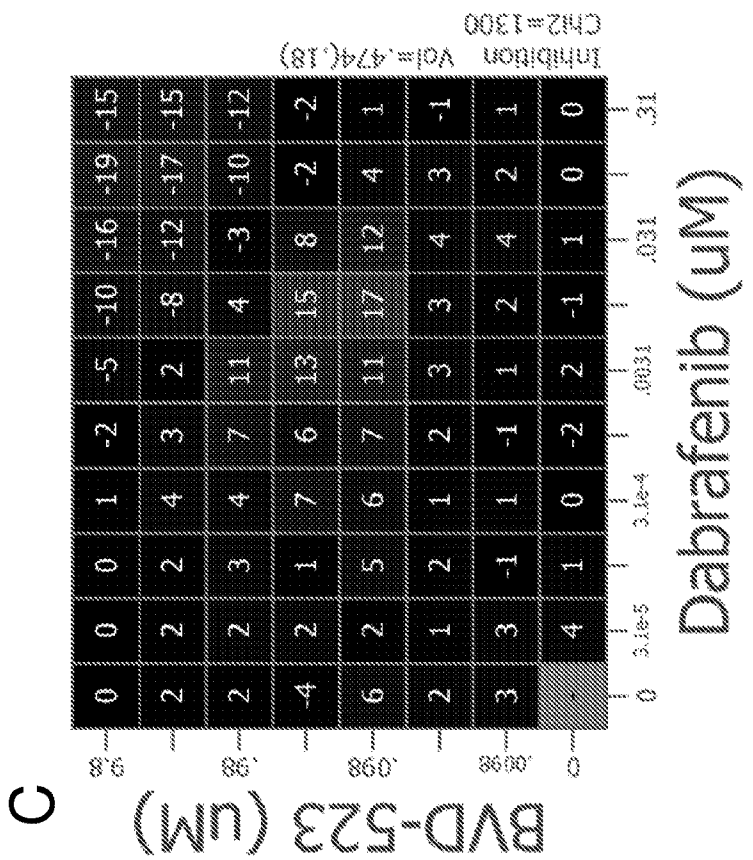

BVD-523 (uM)
9.8
.98
.098
.0098
0
Dabrafenib (uM)
0
3.1e-5
3.1e-4
.0031
.031
.31
Inhibition
N=3
76 76 77 78 77 77 77 75 75 80
75 76 76 78 79 81 77 78 76 78
60 61 62 63 69 78 81 82 79 79
21 27 27 33 36 53 72 80 78 81
11 7 11 14 19 36 63 77 78 79
3 2 3 4 10 24 46 67 77 76
3 4 0 3 7 22 45 68 75 78
- 4 2 2 6 22 42 64 73 76

FIG. 49, Con't


C
BVD-523 (uM)
Dabrafenib (uM)
Inhibition Vol=.474(.18)
CH2=1300

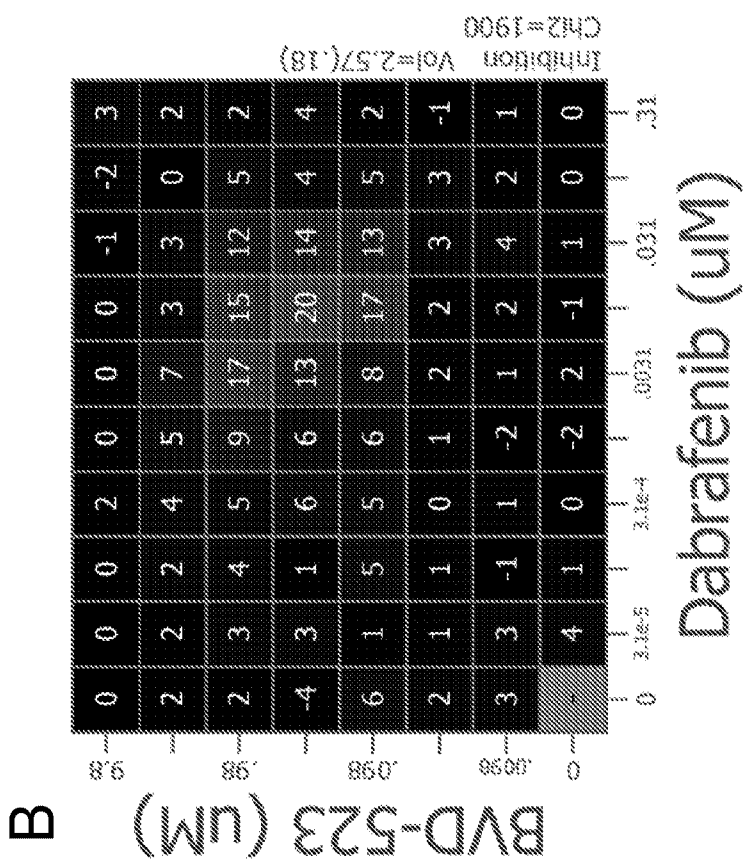

B
BVD-523 (uM)
Dabrafenib (uM)
Inhibition Vol=2.57(.18)
CH2=1900

FIG. 49, Con't

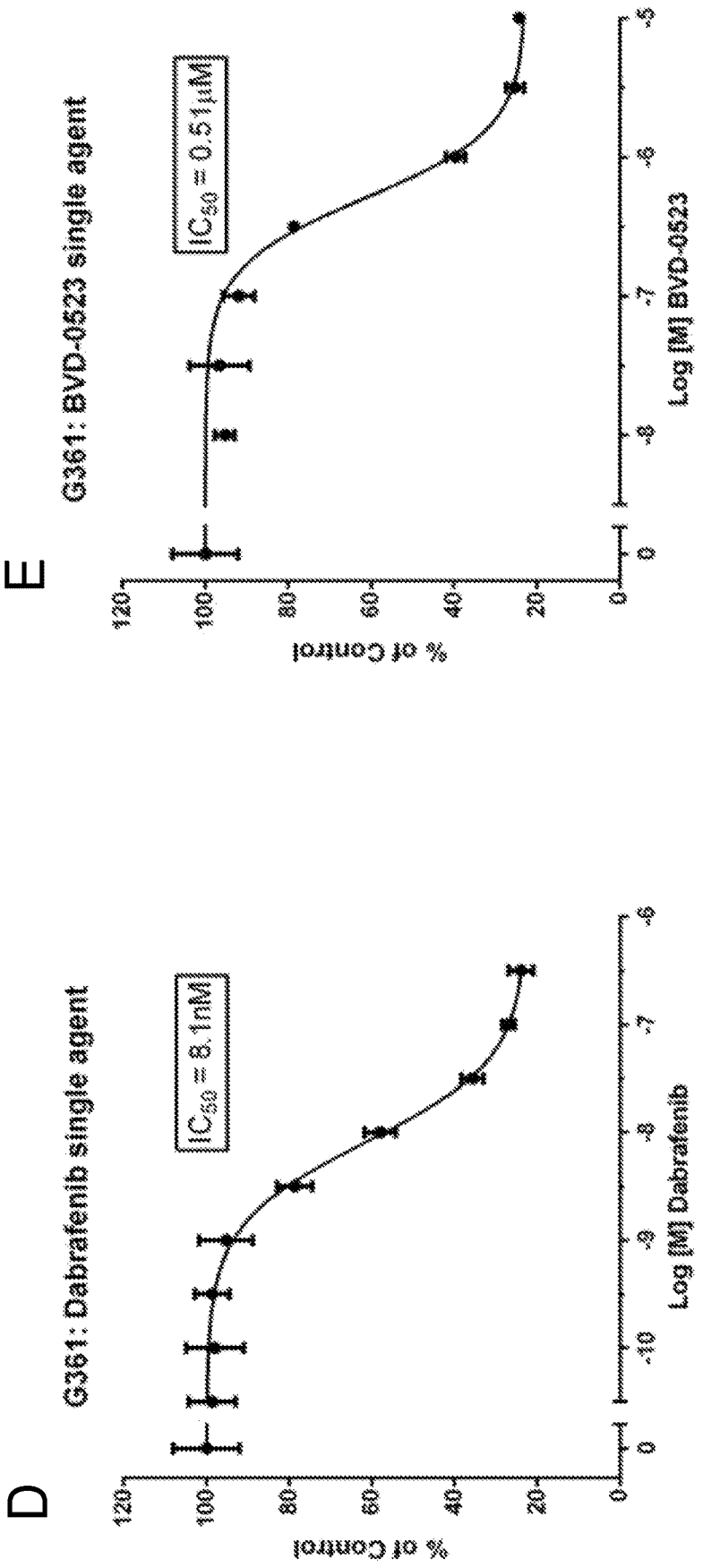

D
G361: Dabrafenib single agent
IC50 = 8.1nM
% of Control
Log [M] Dabrafenib
E
G361: BVD-0523 single agent
IC50 = 0.51μM
% of Control
Log [M] BVD-0523

FIG. 50

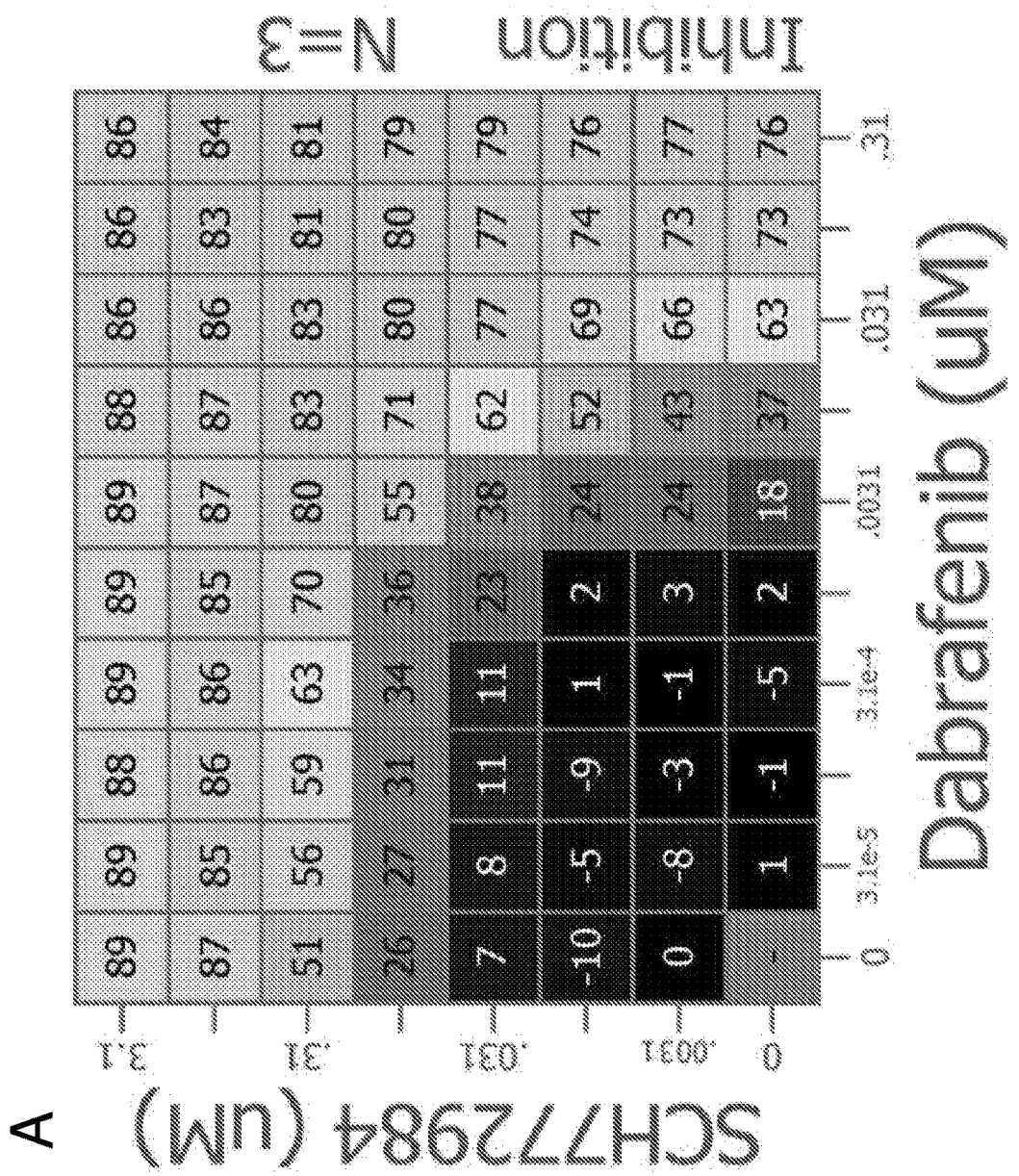

A
SCH772984 (uM)
3.1
.31
.031
.0031
0
Dabrafenib (uM)
0
3.1e-5
3.1e-4
.0031
.031
.31
Inhibition N=3
89 89 88 89 89 88 86 86 86
87 85 86 86 85 86 83 86 84
51 56 59 63 70 80 83 83 81
26 27 31 34 36 55 71 80 79
7 8 11 11 23 38 62 77 79
-10 -5 -9 1 2 24 52 69 76
0 -8 -3 -1 3 24 43 66 77
- 1 -1 -5 2 18 37 63 76

FIG. 50, Con't

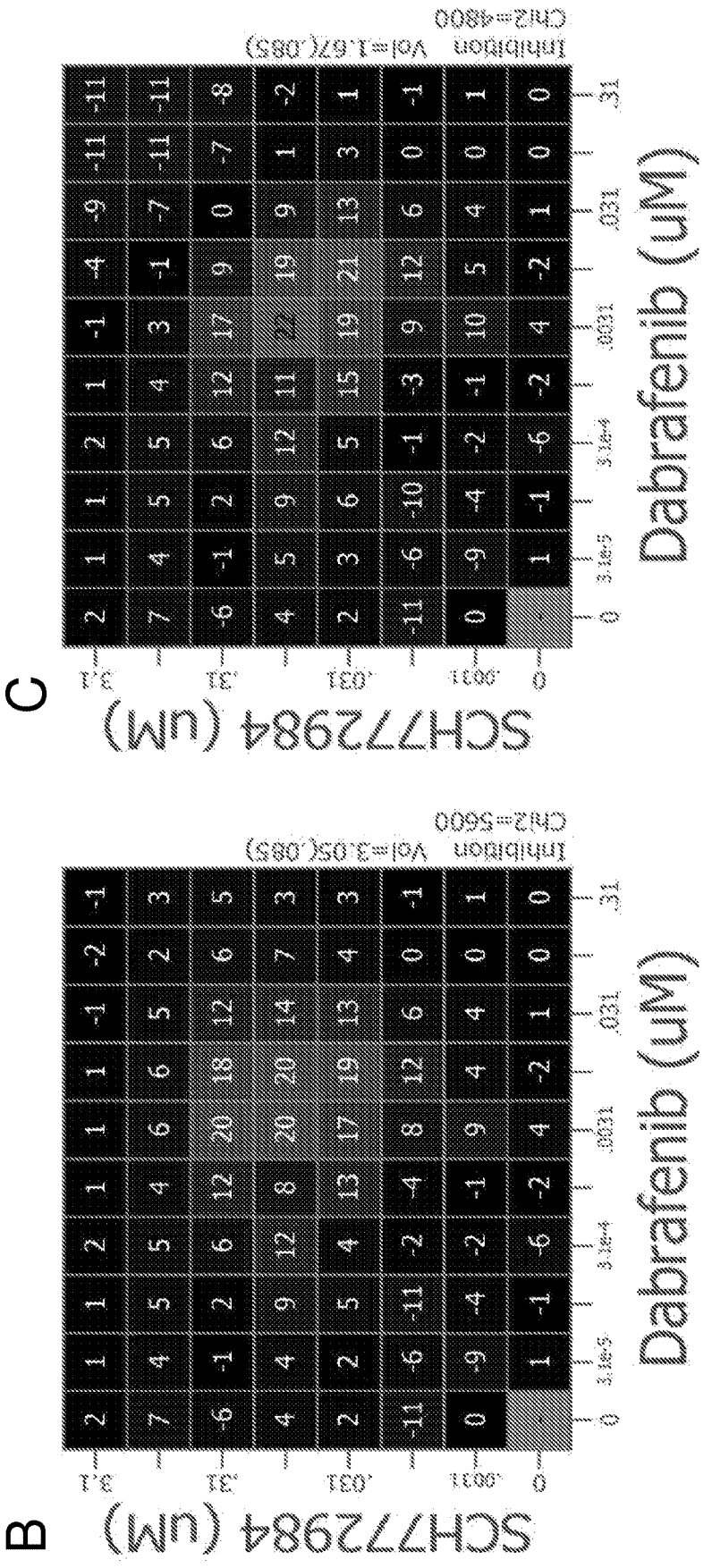
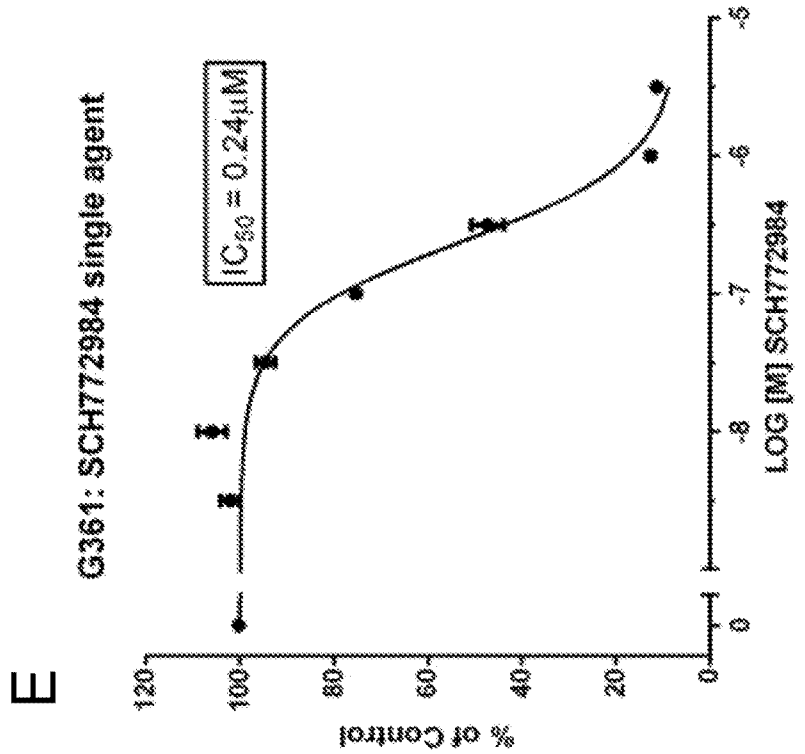

C
SCH772984 (uM)
Dabrafenib (uM)
Inhibition Vol=1.67(.085)
CH2=4800
B
SCH772984 (uM)
Dabrafenib (uM)
Inhibition Vol=3.05(.085)
CH2=5600

FIG. 50, Con't


E
G361: SCH772984 single agent
IC_{50} = 0.24μM
% of Control
LOG [M] SCH772984
120
100
80
60
40
20
0
-5
-6
-7
-8

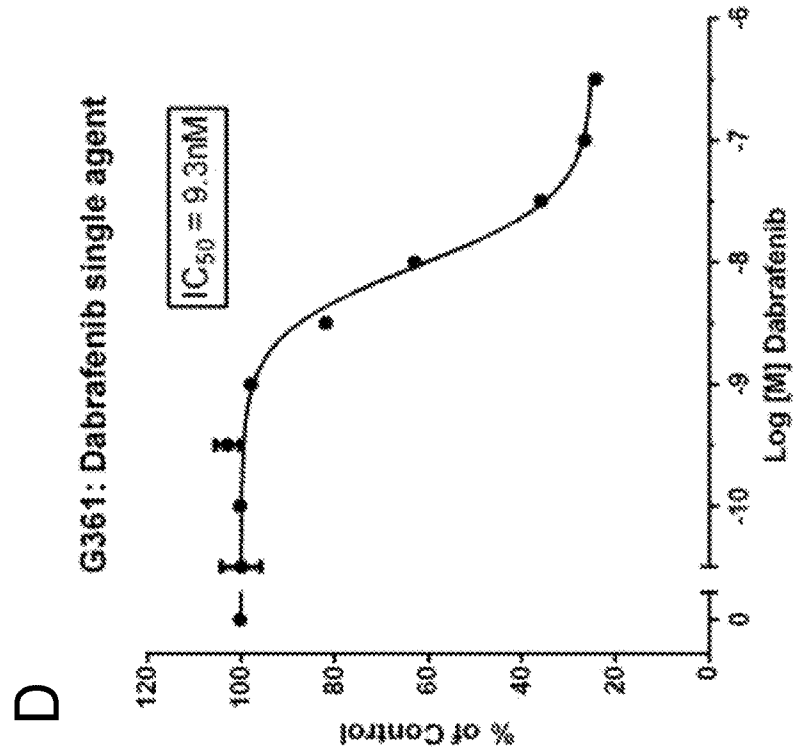

D
G361: Dabrafenib single agent
IC_{50} = 9.3nM
% of Control
Log [M] Dabrafenib
120
100
80
60
40
20
0
-6
-7
-8
-9
-10

FIG. 51

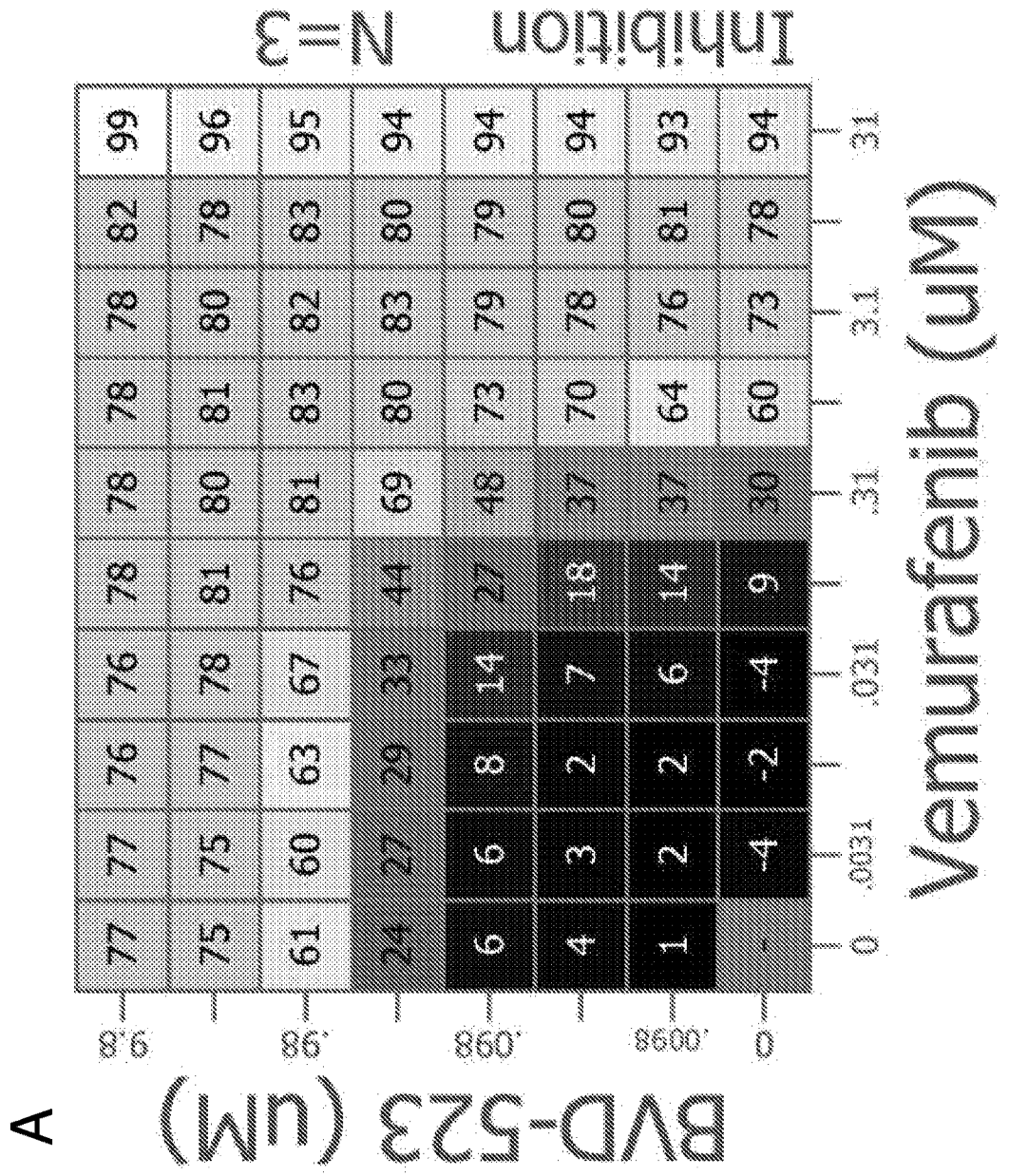

A
BVD-523 (uM)
9.8
2.8
.98
.392
.098
0
Vemurafenib (uM)
0
.0031
.031
.31
3.1
31
Inhibition N=3
99 96 95 94 94 94 93 94
82 78 83 80 79 80 81 78
78 80 82 83 79 78 76 73
78 81 83 80 73 70 64 60
78 80 81 69 48 37 37 30
78 81 76 44 27 18 14 9
76 78 67 33 14 7 6 -4
76 77 63 29 8 2 2 -2
77 75 60 27 6 3 2 -4
77 75 61 24 6 4 1 -

FIG. 51, Con't

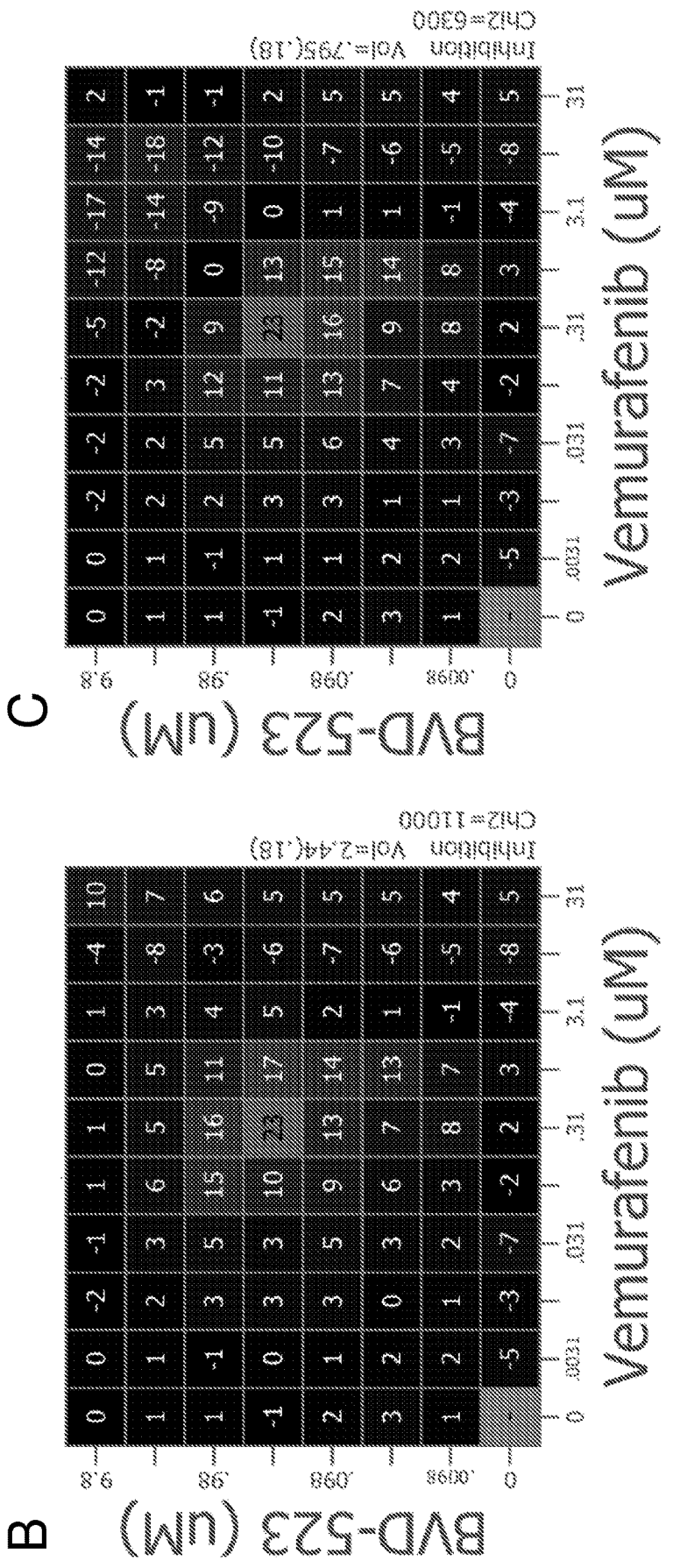
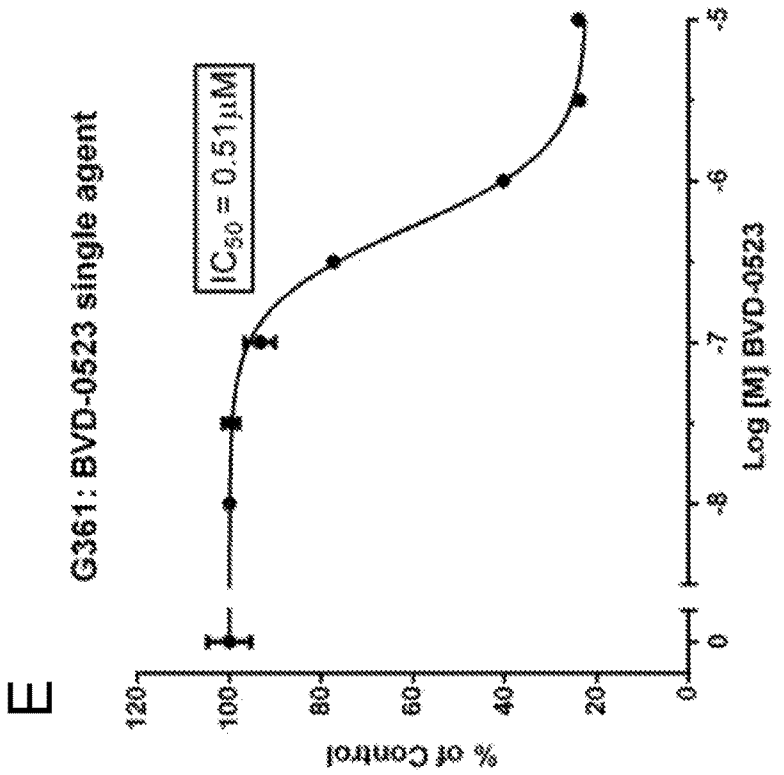

B
BVD-523 (uM)
Vemurafenib (uM)
Inhibition Vol=2.44(.18)
Chi2=11000
C
BVD-523 (uM)
Vemurafenib (uM)
Inhibition Vol=.795(.18)
Chi2=6300

FIG. 51, Con't


E
G361: BVD-0523 single agent
IC50 = 0.51μM
% of Control
Log [M] BVD-0523
120
100
80
60
40
20
0
-5
-6
-7
-8

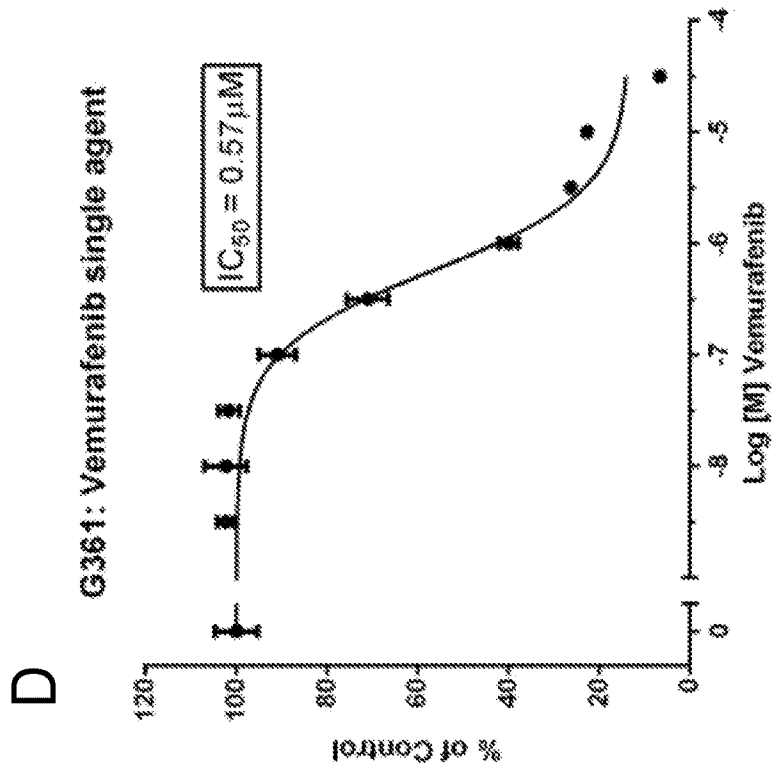

D
G361: Vemurafenib single agent
IC50 = 0.57μM
% of Control
Log [M] Vemurafenib
120
100
80
60
40
20
0
-4
-5
-6
-7
-8

FIG. 52

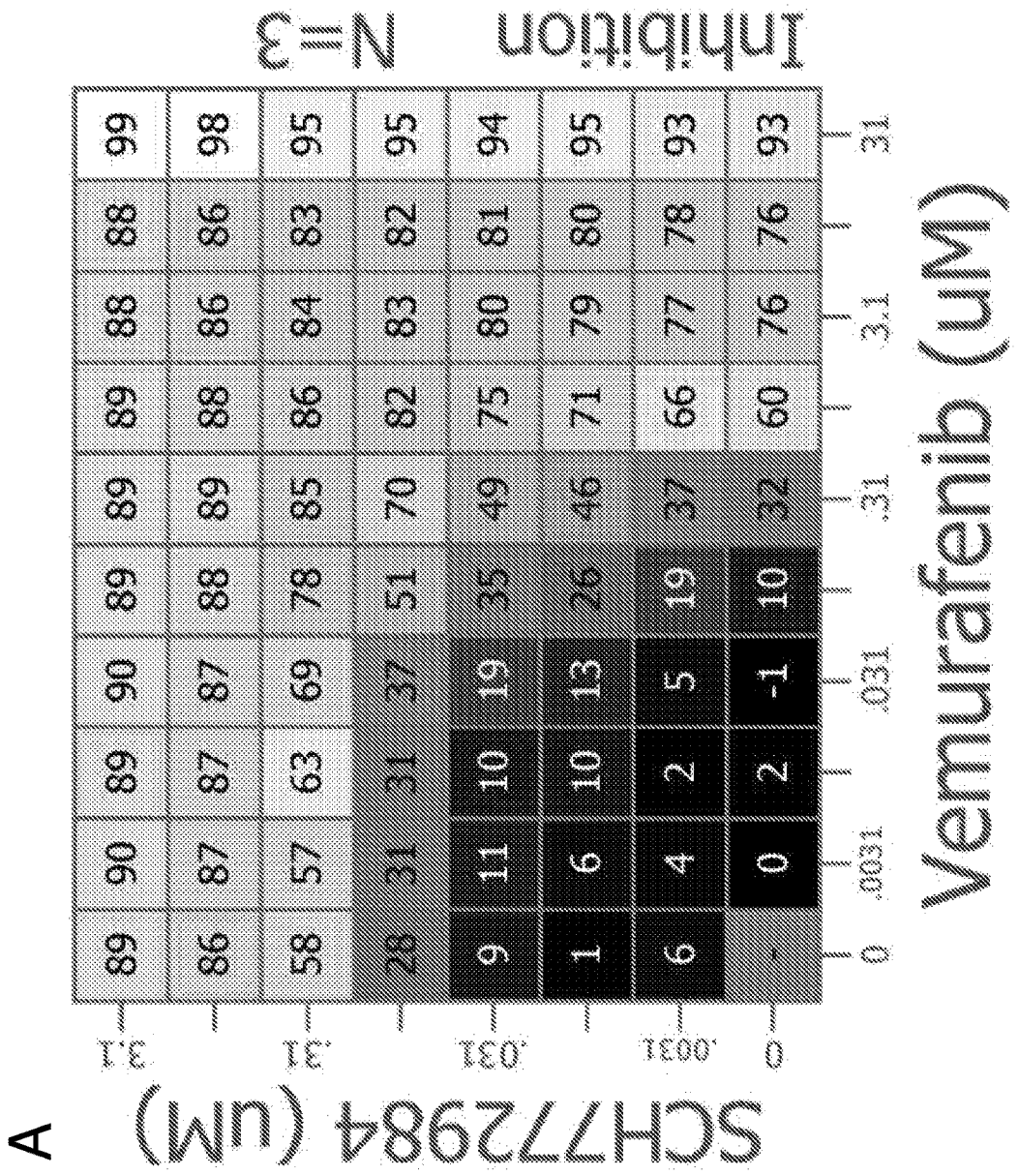

A
SCH772984 (uM)
3.1
.31
.031
.0031
0
Vemurafenib (uM)
0
.0031
.031
.31
3.1
31
Inhibition N=3
89 90 89 89 89 88 88 99
86 87 87 88 89 88 86 98
58 57 63 78 85 86 84 83 95
28 31 31 37 51 70 82 83 82 95
9 11 10 19 35 49 75 80 81 94
1 6 10 13 26 46 71 79 80 95
6 4 2 5 19 37 66 77 78 93
- 0 2 -1 10 32 60 76 76 93

FIG. 52, Con't

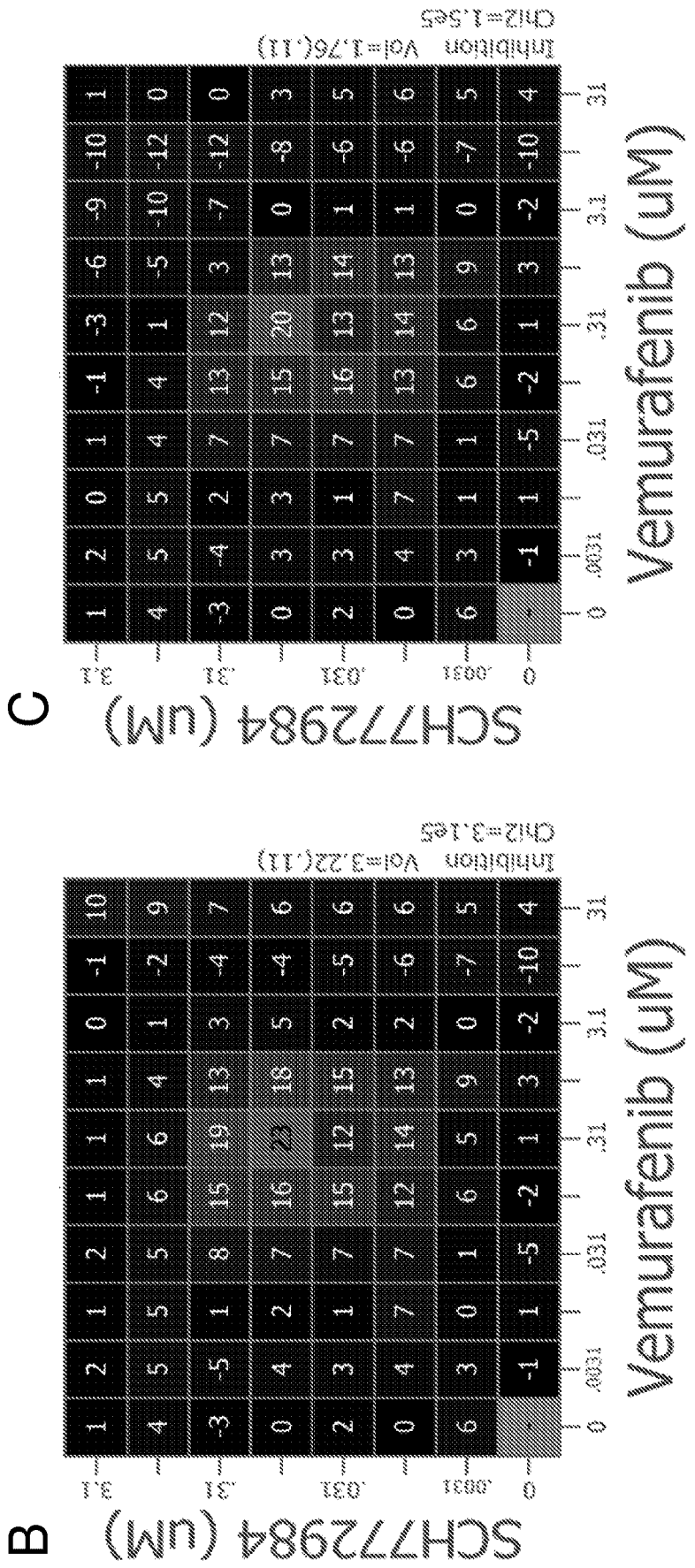
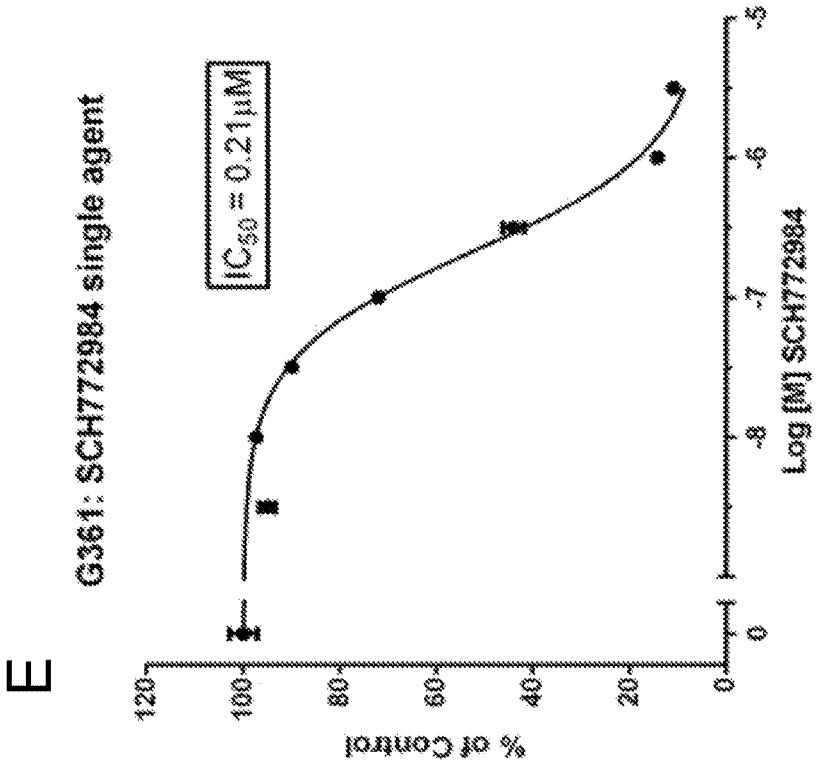

C
SCH772984 (uM)
Vemurafenib (uM)
Inhibition Vol=1.76(.11)
Chi2=1.565
B
SCH772984 (uM)
Vemurafenib (uM)
Inhibition Vol=3.22(.11)
Chi2=3.165

FIG. 52, Con't


E
G361: SCH772984 single agent
IC50 = 0.21μM
% of Control
Log [M] SCH772984
120
100
80
60
40
20
0
-5
-6
-7
-8

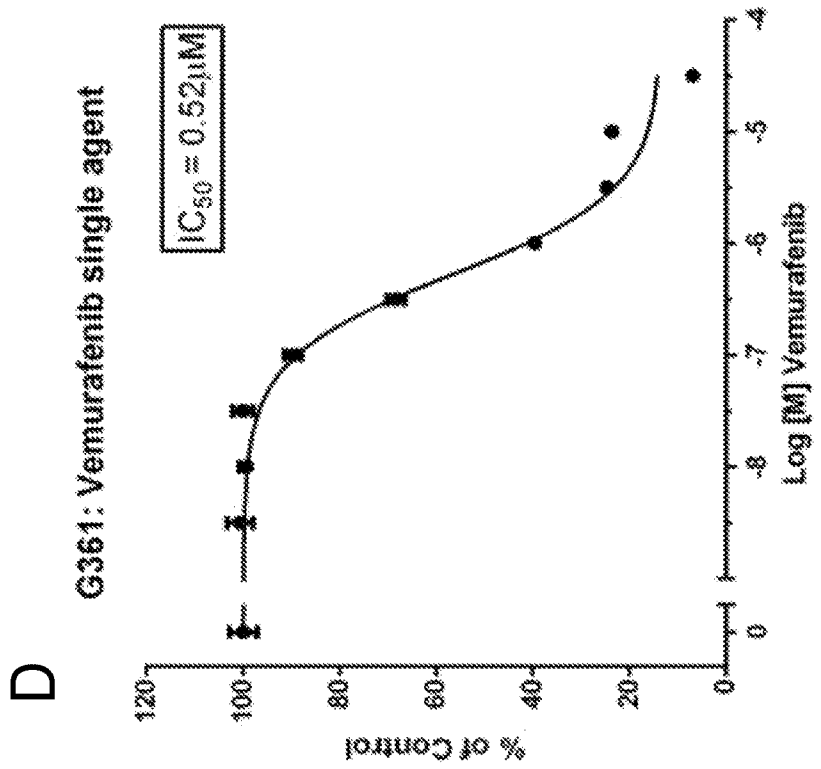

D
G361: Vemurafenib single agent
IC50 = 0.52μM
% of Control
Log [M] Vemurafenib
120
100
80
60
40
20
0
-4
-5
-6
-7
-8

FIG. 53

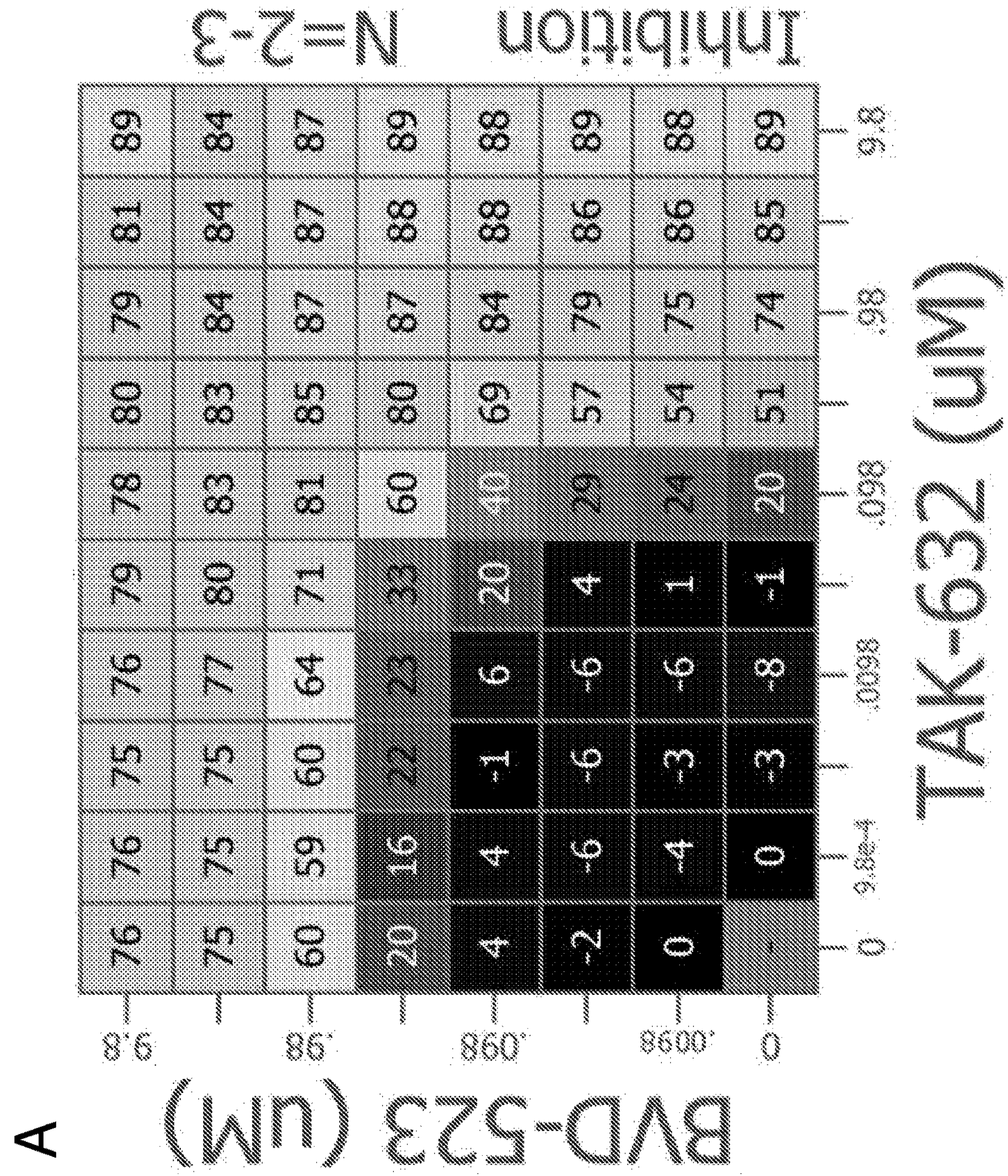

A
Inhibition
N=2-3
BVD-523 (uM)
9.8
.98
.098
.0098
0
TAK-632 (uM)
0
9.8e-4
.0098
.098
.98
9.8
76 76 75 76 79 78 80 79 81 89
75 75 75 77 80 83 83 84 84 84
60 59 60 64 71 81 85 87 87 87
20 16 22 23 33 60 80 87 88 89
4 4 -1 6 20 40 69 84 88 88
-2 -6 -6 -6 4 29 57 79 86 89
0 -4 -3 -6 1 24 54 75 86 88
- 0 -3 -8 -1 20 51 74 85 89

FIG. 53, Con't

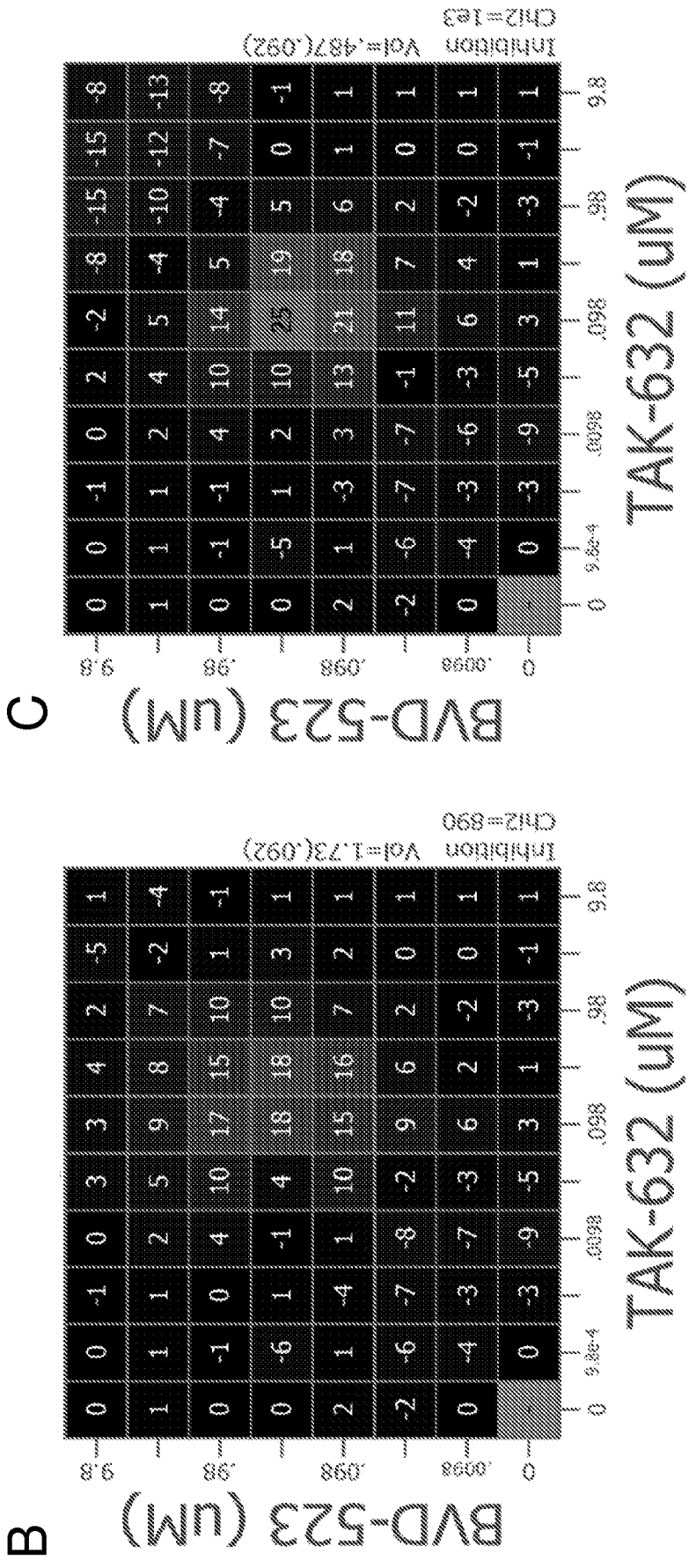

B
BVD-523 (uM)
TAK-632 (uM)
Inhibition
Val=1.73(.092)
Ch2=890
C
BVD-523 (uM)
TAK-632 (uM)
Inhibition
Val=.487(.092)
Ch2=183

FIG. 53, Con't

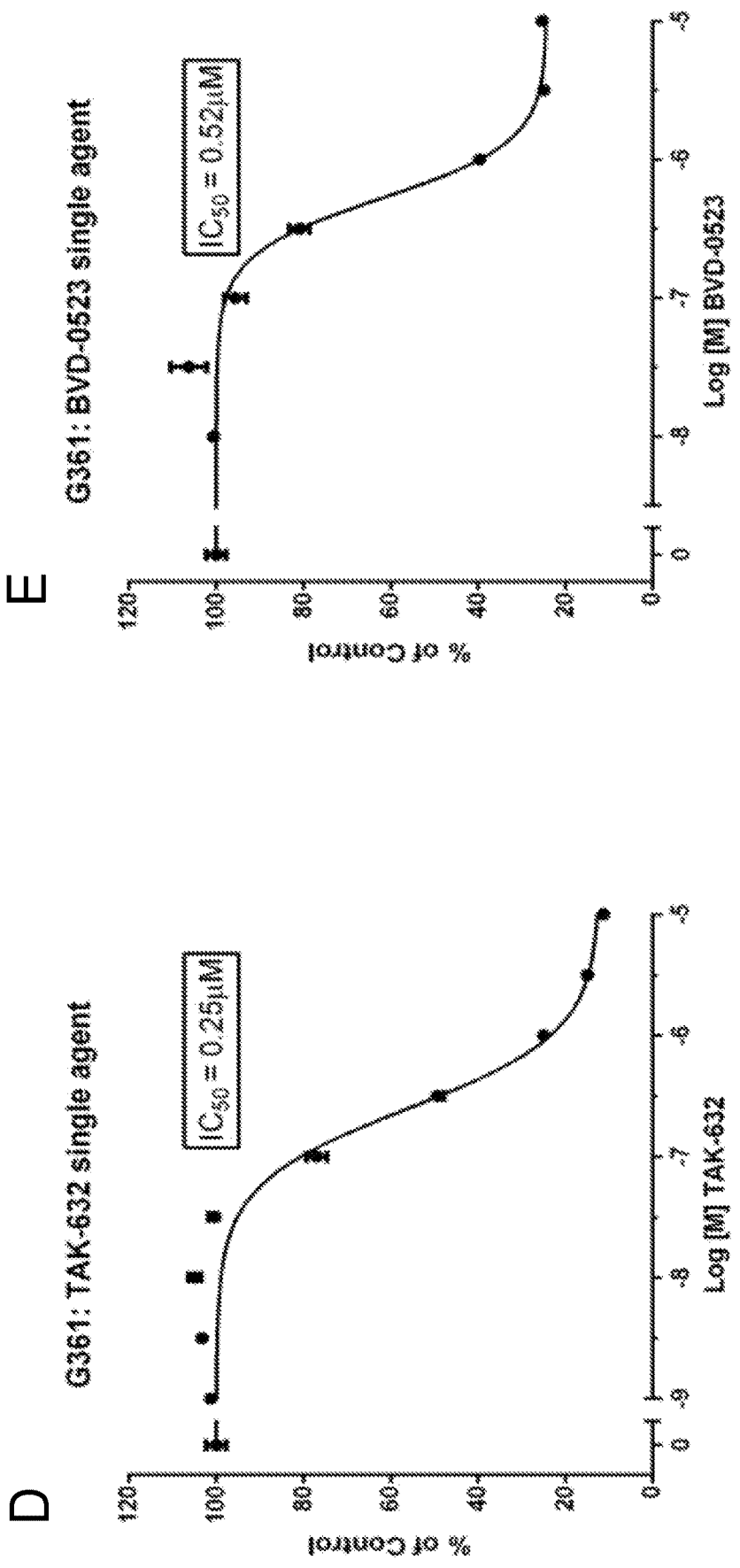

D
G361: TAK-632 single agent
IC50 = 0.25μM
% of Control
Log [M] TAK-632
E
G361: BVD-0523 single agent
IC50 = 0.52μM
% of Control
Log [M] BVD-0523

FIG. 54

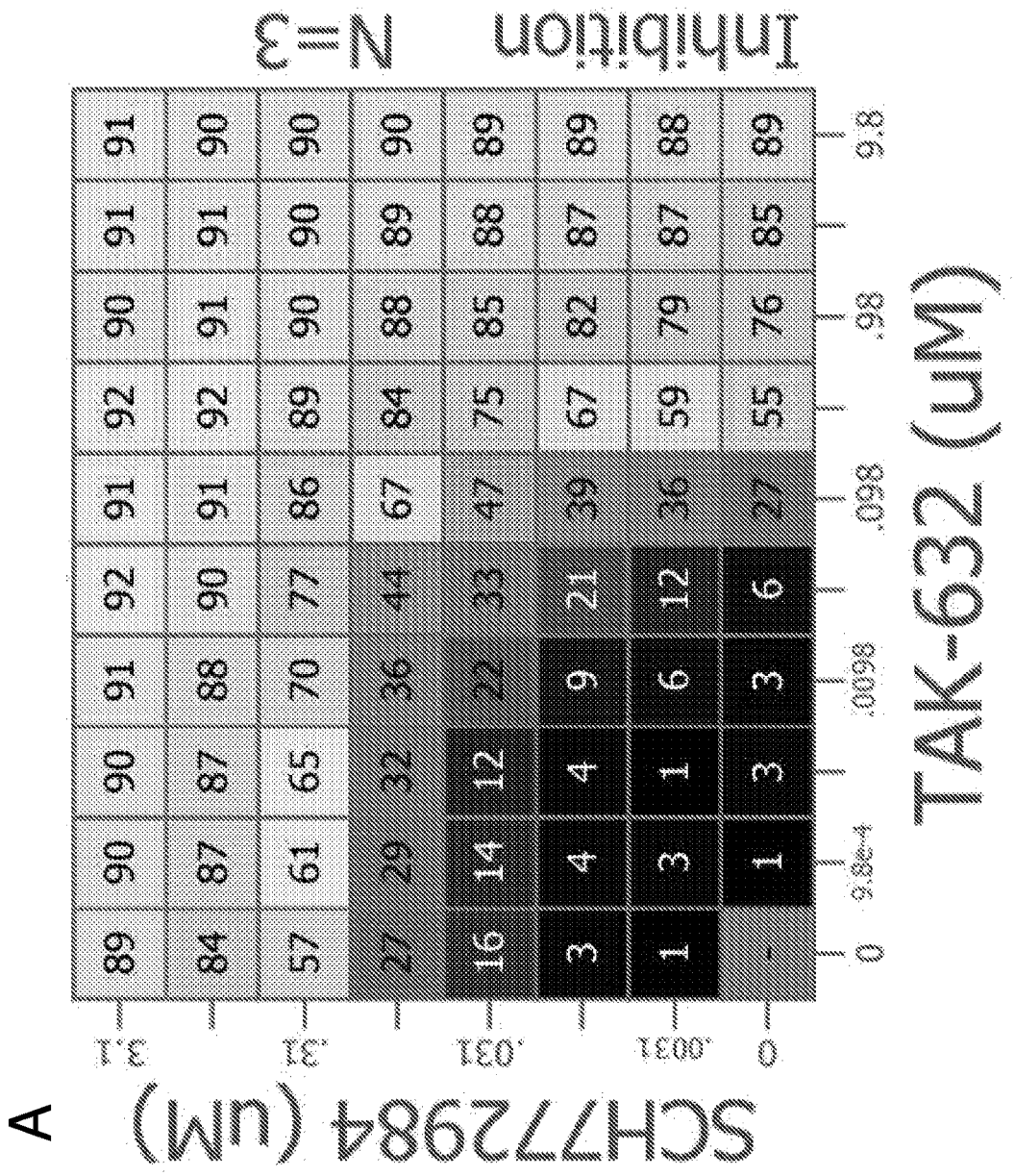
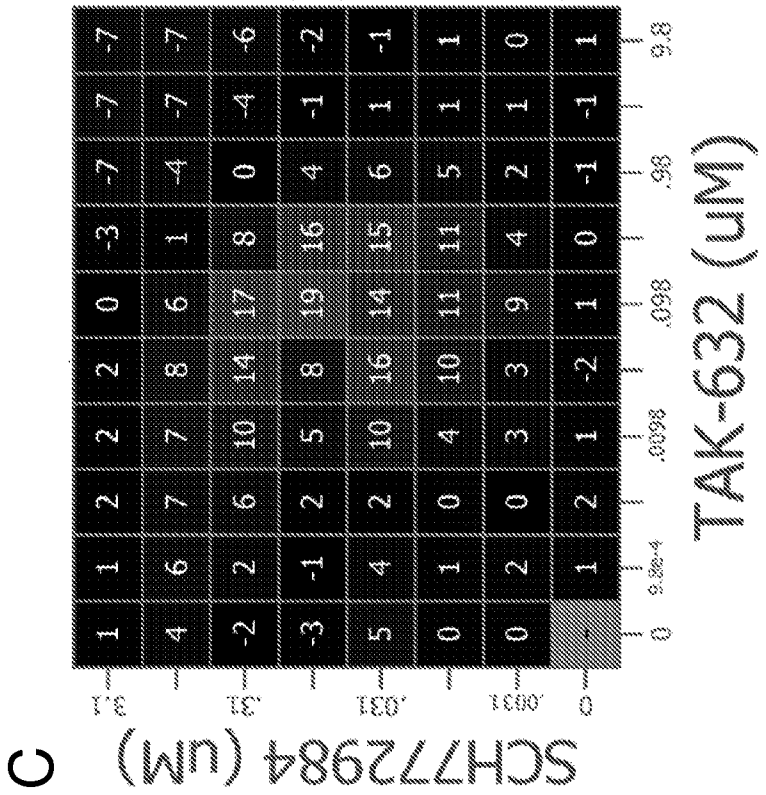

A
SCH772984 (uM)
3.1
.31
.031
0
Inhibition N=3
89 90 90 91 92 91 92 90 91 91
84 87 87 88 90 91 92 91 90 90
57 91 65 70 77 86 89 90 90 90
27 29 32 36 44 67 84 88 89 90
16 14 12 22 33 47 75 85 88 89
3 4 4 9 21 39 67 82 87 89
1 3 1 6 12 36 59 79 87 88
- 1 3 3 6 27 55 76 85 89
0 9.8e-4 .0098 .098 .98 9.8
TAK-632 (uM)

FIG. 54, Con't


C
SCH772984 (uM)
TAK-632 (uM)
Inhibition Vol=2.27(.18)
Ch2=1200

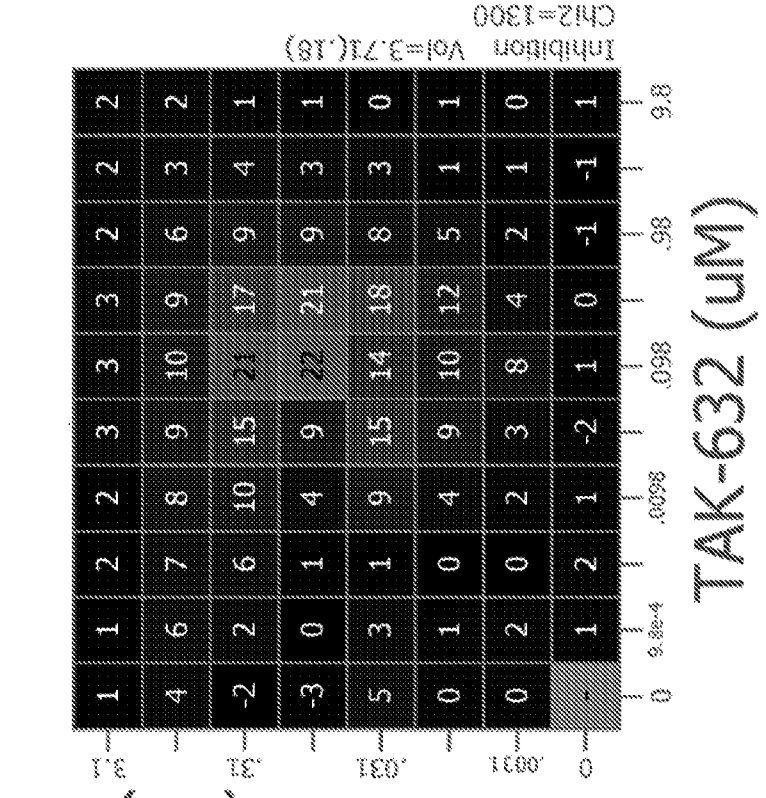
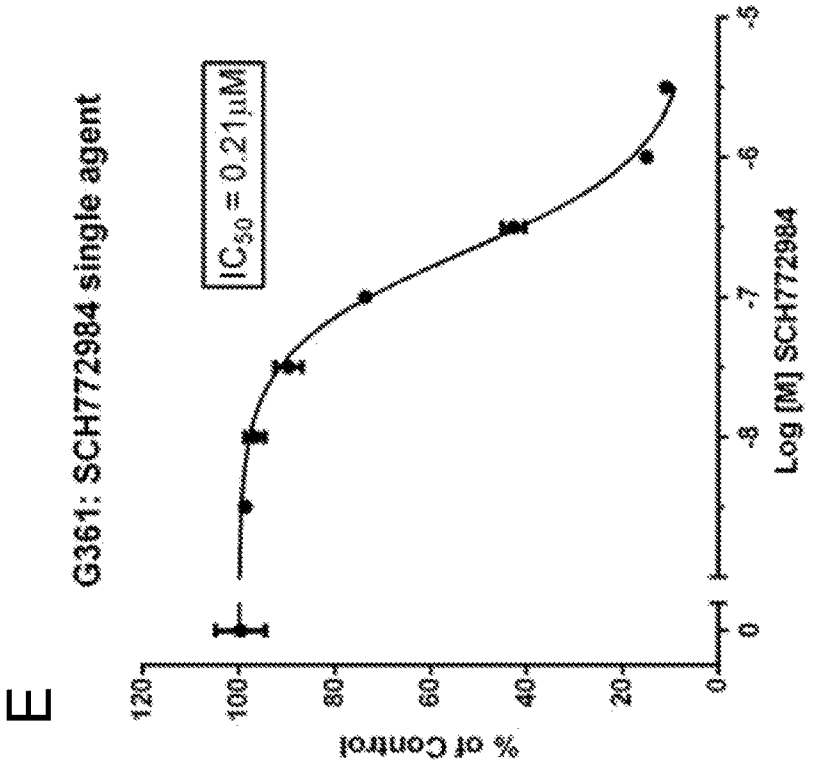
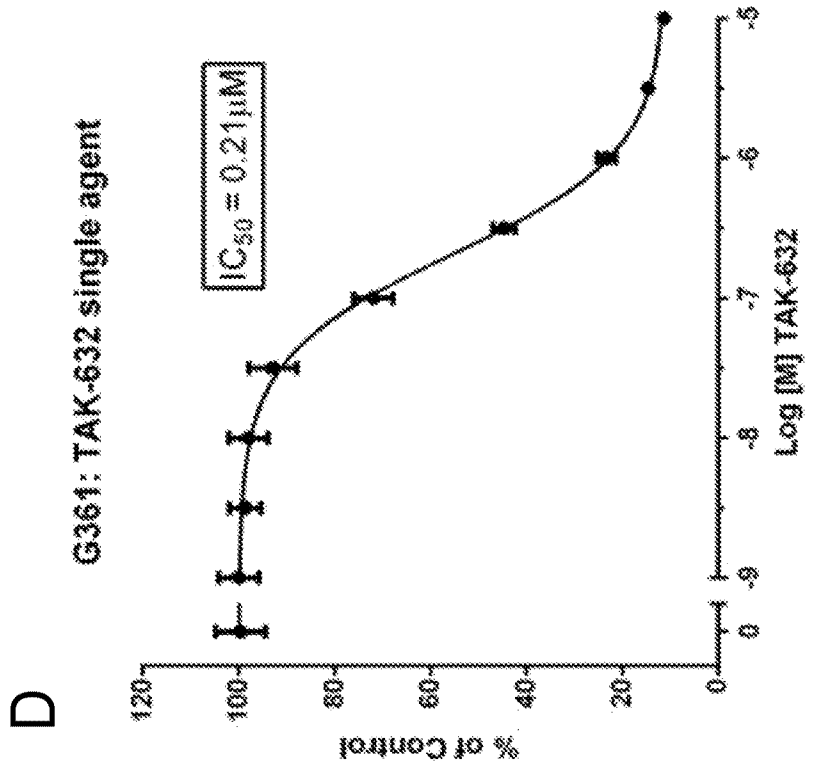

B
SCH772984 (uM)
TAK-632 (uM)
Inhibition Vol=3.71(.18)
Ch2=1300

FIG. 54, Con't


E
G361; SCH772984 single agent
IC50 = 0.21μM
% of Control
Log [M] SCH772984
120
100
80
60
40
20
0
-5
-6
-7
-8
0


D
G361; TAK-632 single agent
IC50 = 0.21μM
% of Control
Log [M] TAK-632
120
100
80
60
40
20
0
-5
-6
-7
-8
-9
0

DEMANDE OU BREVET VOLUMINEUX

LA PRÉSENTE PARTIE DE CETTE DEMANDE OU CE BREVET COMPREND PLUS D'UN TOME.

CECI EST LE TOME 1 DE 2
CONTENANT LES PAGES 1 À 171

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